How Far Can We Reach With Emerging Generation Technologies at the Global Scale?

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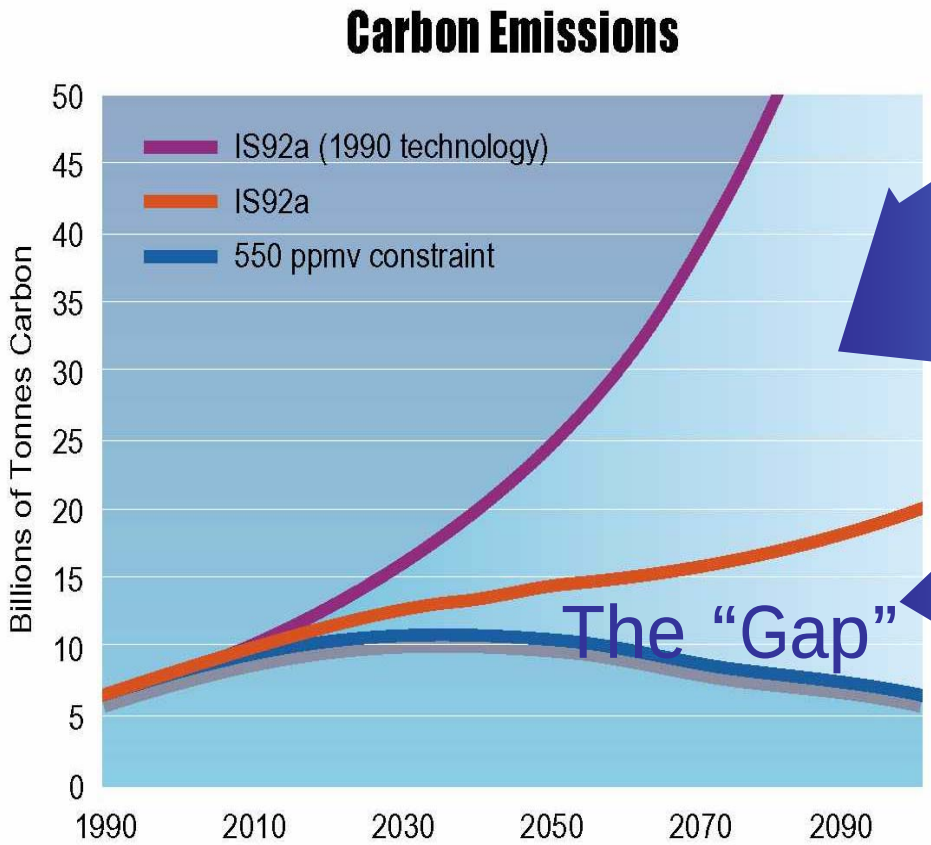
Materials online at: http://rael.berkeley.edu

California Climate Change Conference,
Sacramento, CA September 13, **2007**

Efficiency Improvements and New Technology Vitally Needed, Under-Emphasized



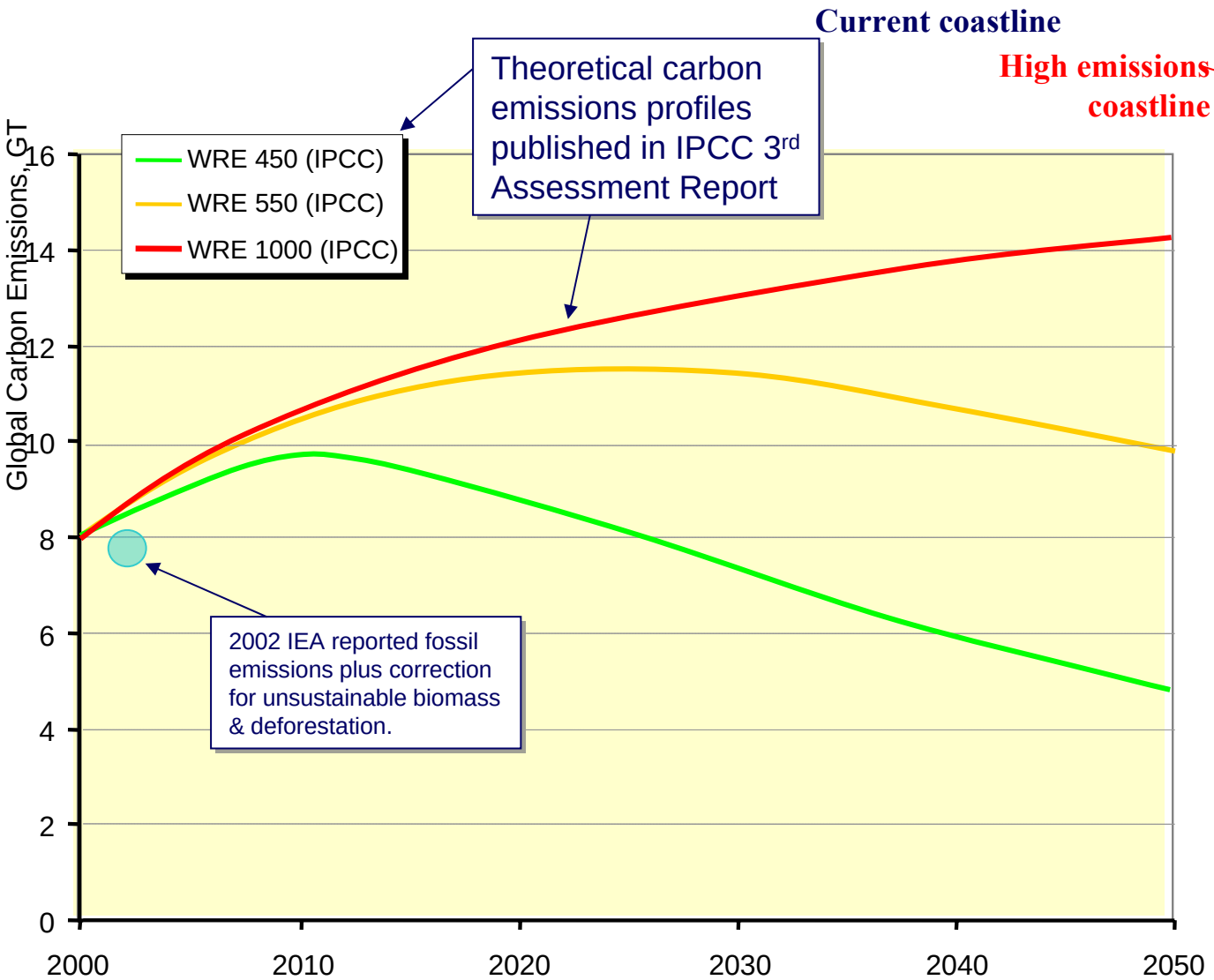
Assumes *Significant* Advances:

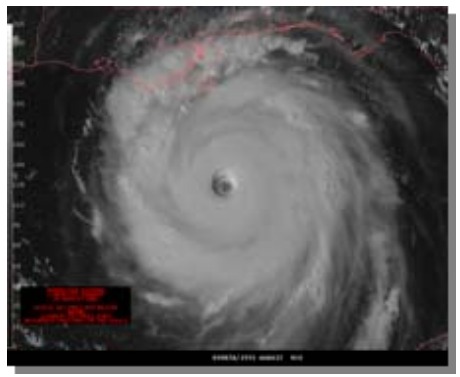
- Energy intensity
- Nuclear
- Renewables

Gap Technologies:

- Carbon capture and storage
- H_2 novel storage and advanced transportation
- Nano/Bio-technologies
- Next generation solar

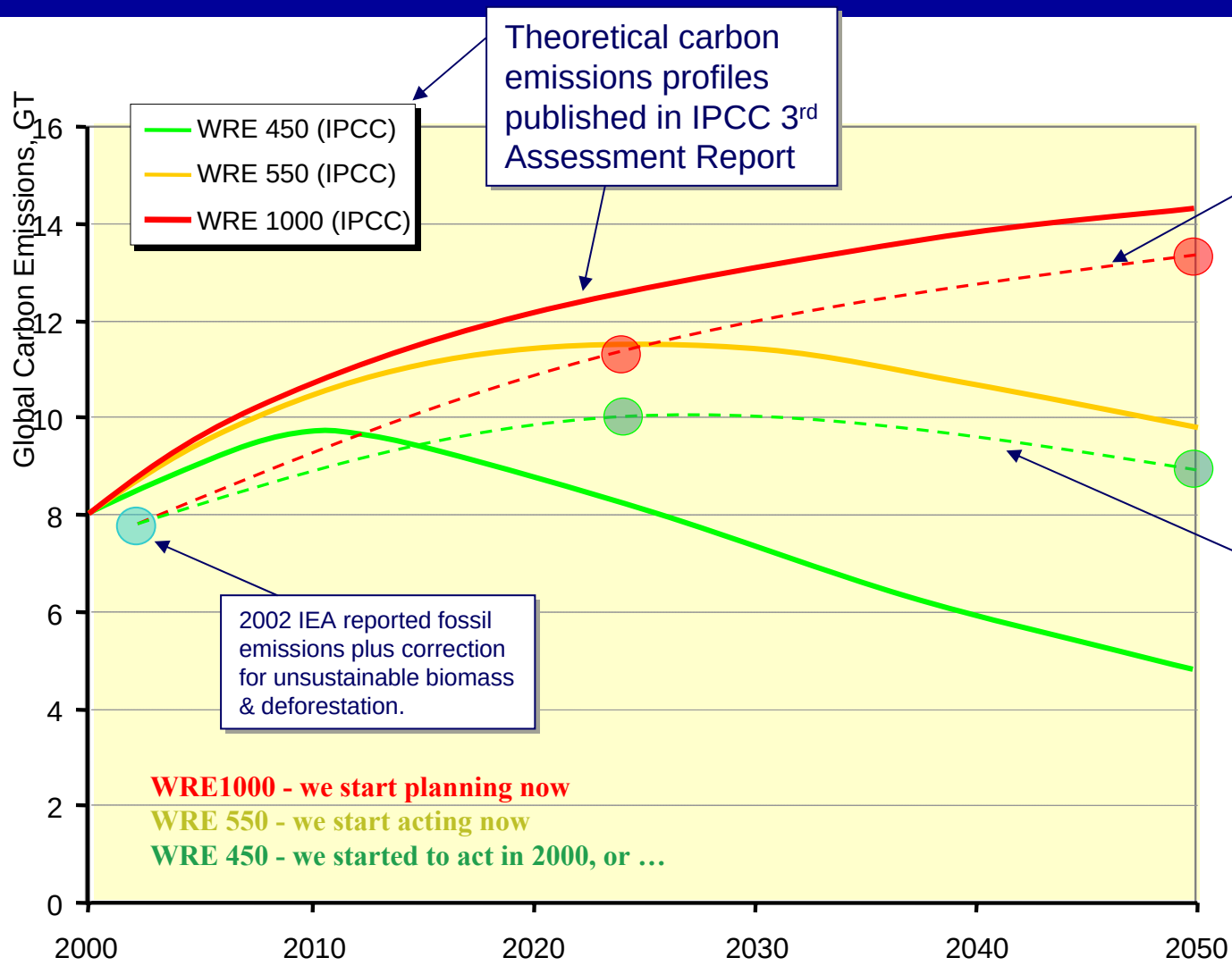
High and low carbon pathways





Thanks to the World Business Council for Sustainable Development

High and low carbon pathways



>900 ppm Trajectory Energy by 2050:

- **Coal over 2x, no Carbon Capture & Storage (CCS), some coal to liquids.**
- **Oil up 50%**
- **Gas over 2x**
- **Biofuels make up 10% of vehicle fuel mix.**
- Electricity 1/3 of final energy.
- **Modest increase in nuclear.**
- **Renewables provide 1/3 of electricity generation.**
- Vehicle efficiency up 50%.

<550 ppm Trajectory Energy by 2050:

- **Coal up 50%, but half of power stations use CCS.**
- Oil down 10-15%.
- **Gas nearly 2-3x (note: adds volatility)**
- **Biofuels make up 20% of vehicle fuel mix.**
- **Green Hydrogen in use**
- **Strong shift to electricity as final energy (~50% final energy).**
- **Large increase in nuclear.**
- **Renewables provide half of electricity generation.**
- **Vehicle efficiency up 100%**
- **Sustainable biomass practices**

Global Forecasts, Economics and Energy

Impact ∝ Population x GDP/capita x carbon/GDP

Population

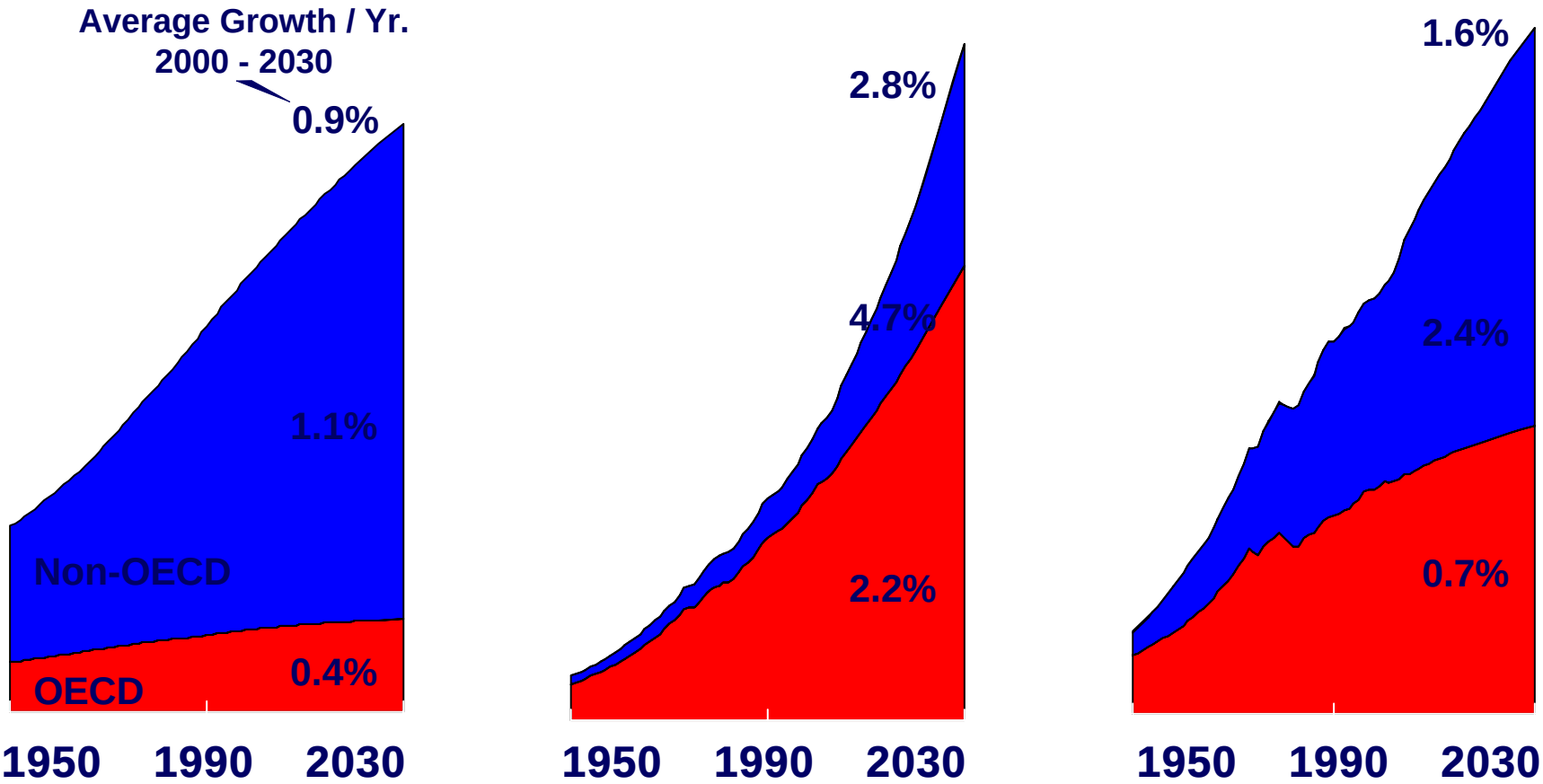
Billions

GDP

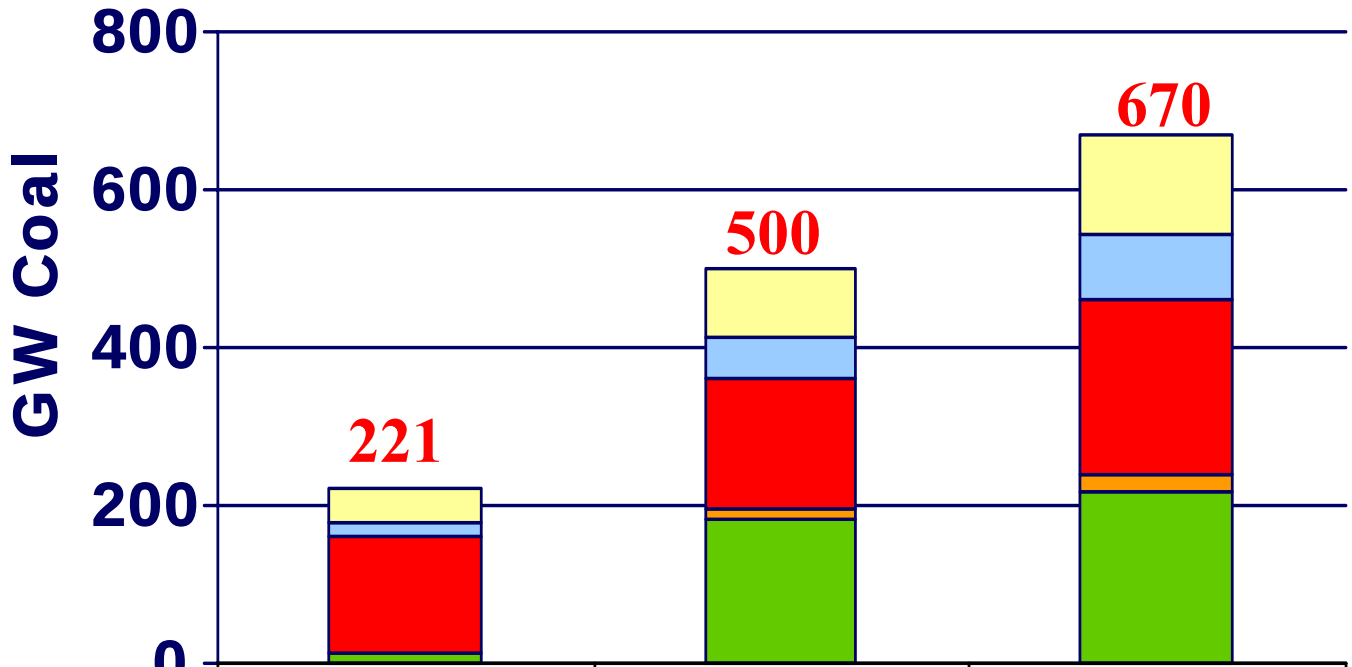
Trillion (2000$)

Energy Demand

MBDOE



New Coal by the Decades



	2003-2010	2011-2020	2021-2030
Other Developing	43	90	128
India	16	48	79
China	150	168	226
Transition	1	11	19
OECD	12	184	218

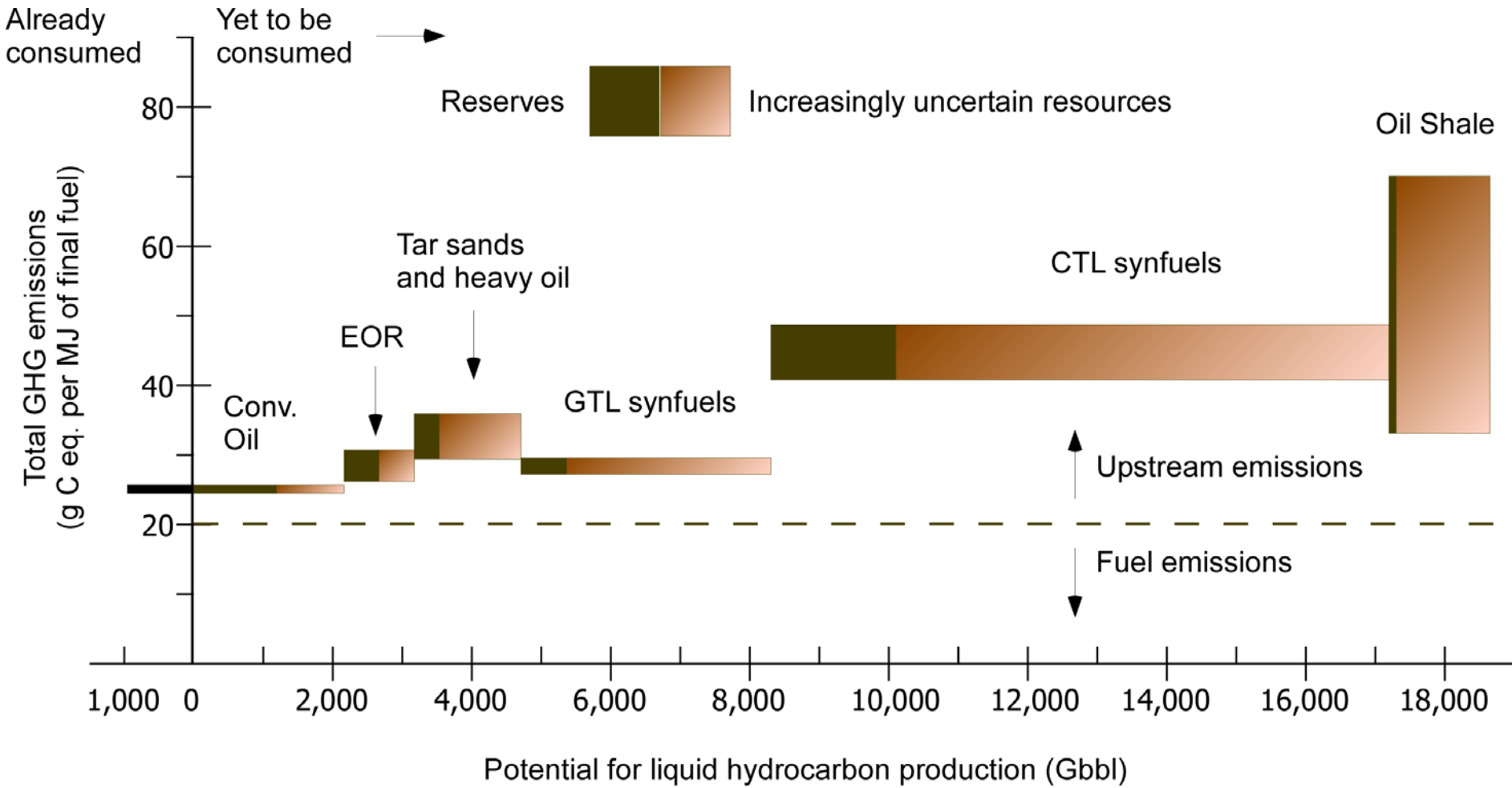
>$1 trillion in capital

Source: IEA, WEO 2004


Athabasca basin tar sand mine:
10% bitumen by weight in the soil.
~ $30/barrel of energy required to refine

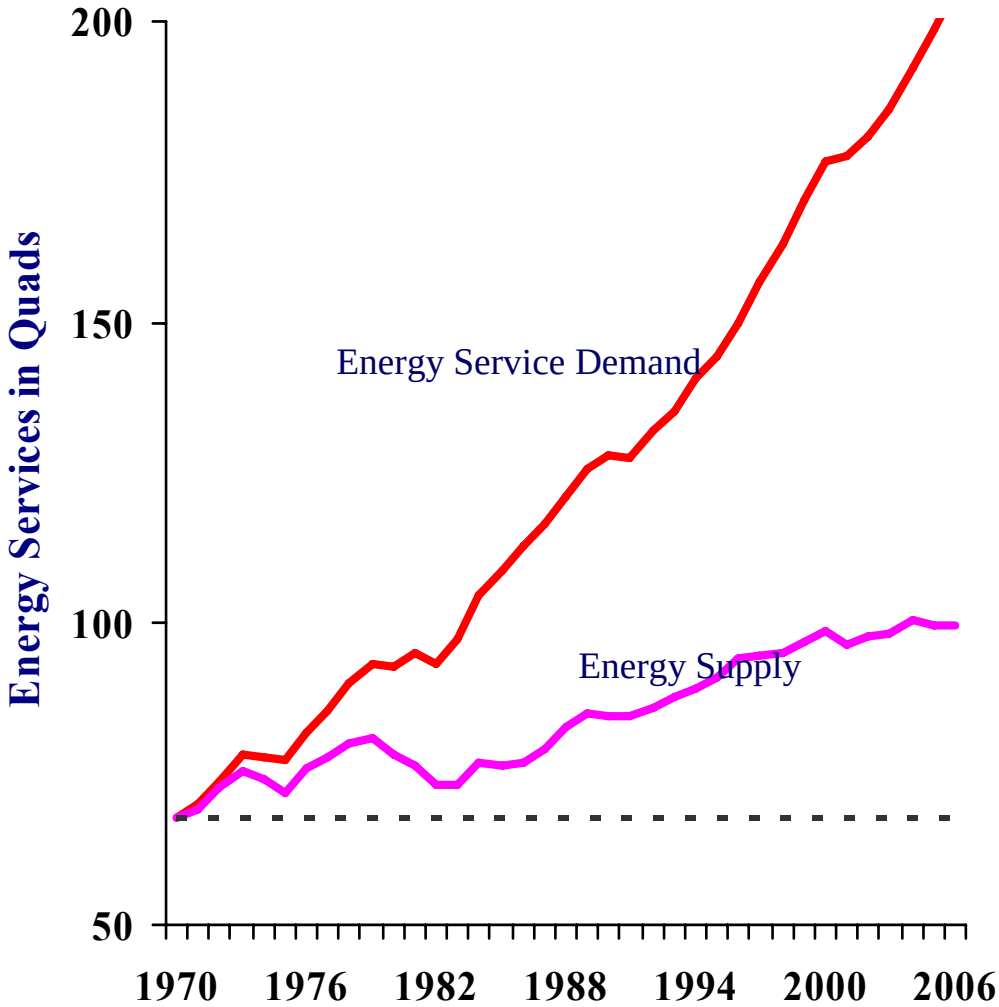

$CH_4 \rightarrow H_2S$ separation, then H_2 & elemental sulfur separation

We are running out of atmosphere *much* faster than fossil fuels … at *all* price points



Source: Brandt and Farrell (2006) ***Environmental Research Letters (erl.iop.org)***

The Energy Efficiency Big Picture (United States)



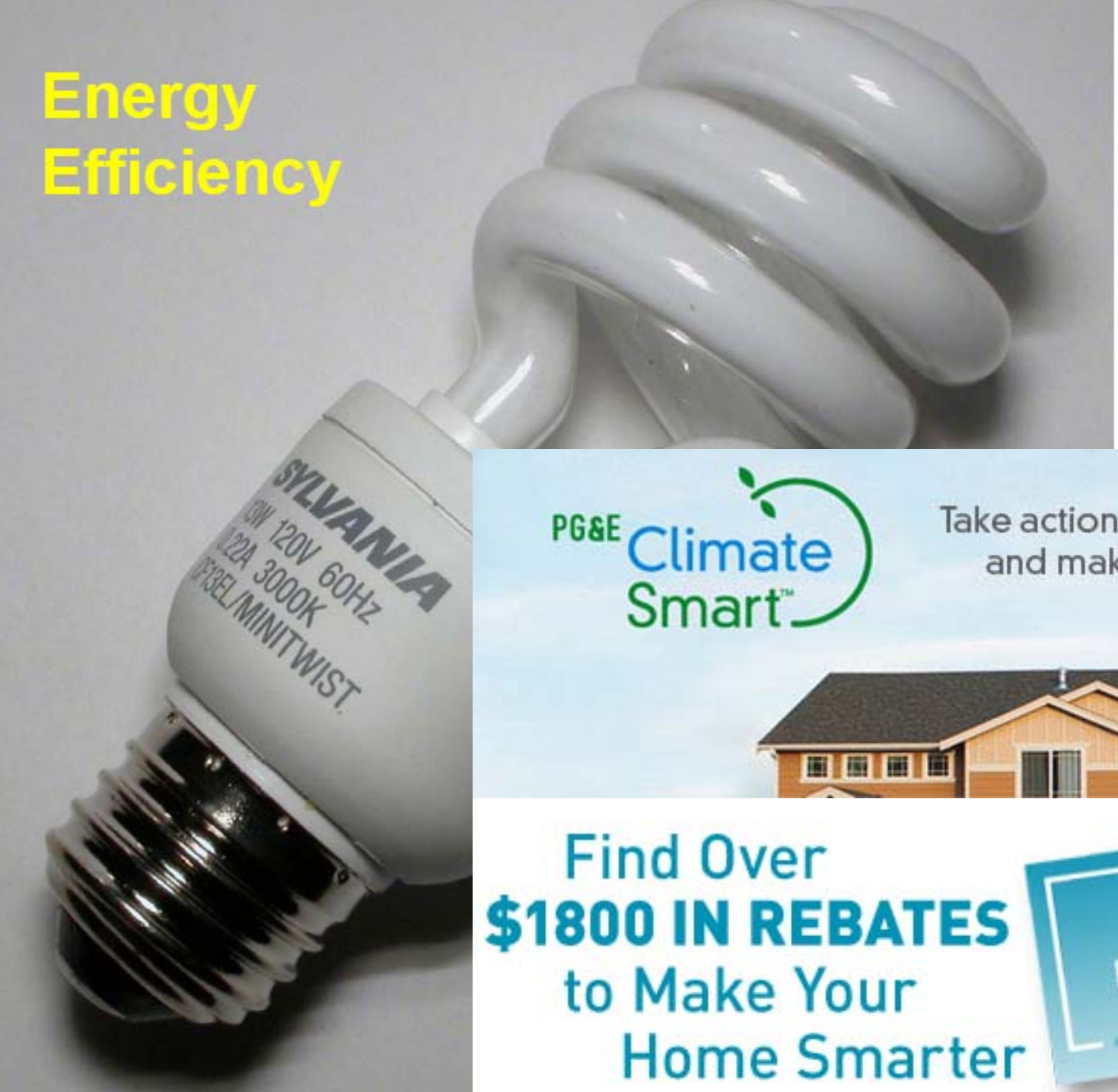
Since 1970, *energy efficiency* has met 3/4 of new energy service demands in the U.S, while *new energy supplies* have contributed less than 1/4 of new energy service demands.

Inside the San Francisco Moscone Center

The Many Values of Efficiency:

$400,000 saved per year with new lights

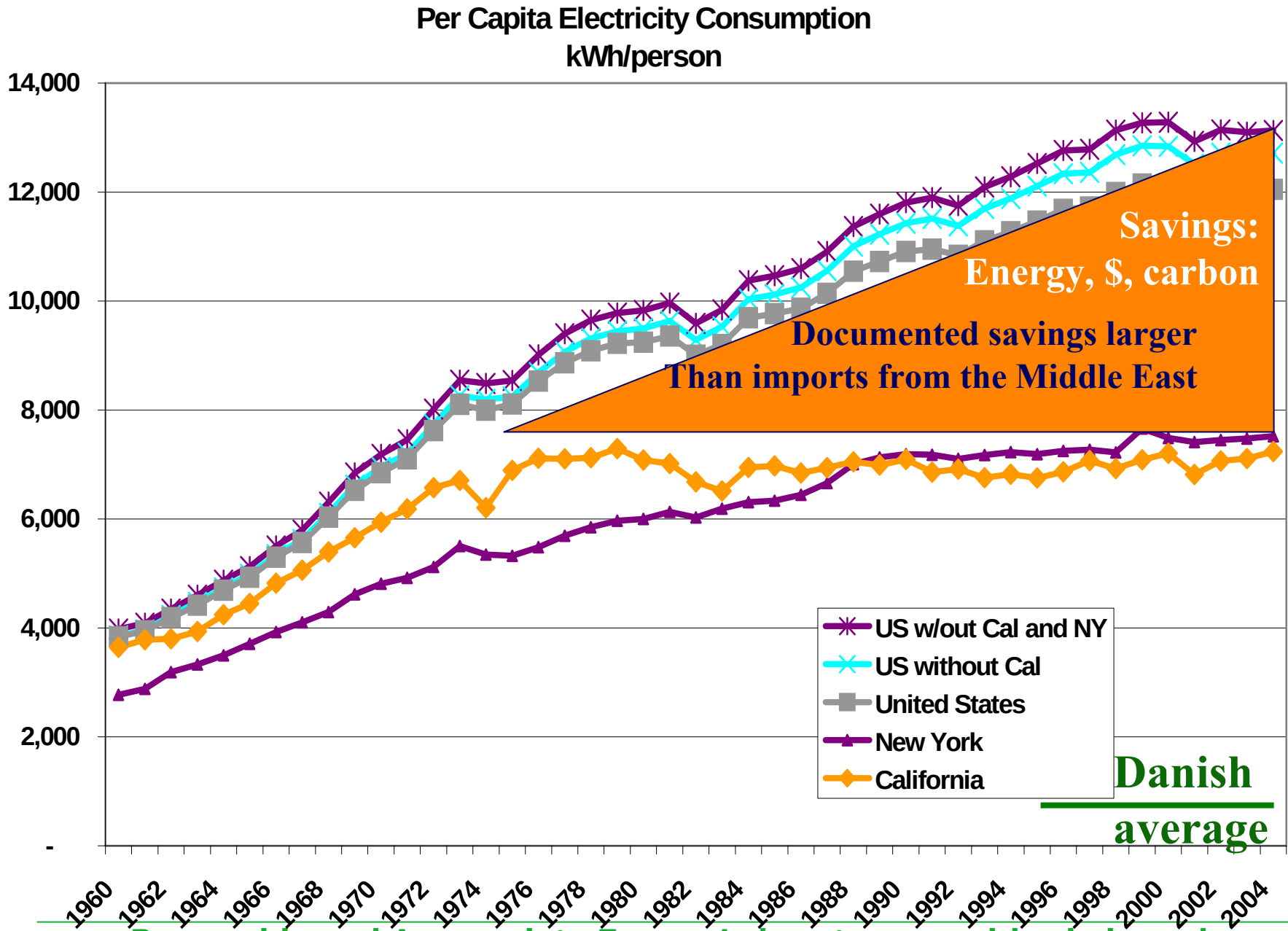
Energy Efficiency



PG&E Climate Smart™

Take action with ClimateSmart™ and make your energy use "climate neutral"

Find Over
$1800 IN REBATES
to Make Your
Home Smarter


Per Capita Electricity Consumption
kWh/person
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
Savings:
Energy, $, carbon
Documented savings larger
Than imports from the Middle East
US w/out Cal and NY
US without Cal
United States
New York
California
Danish
average

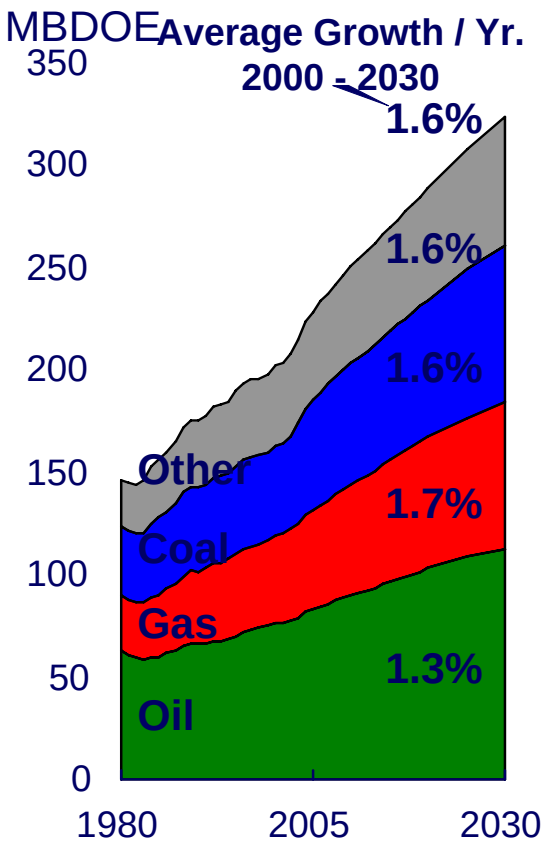
Global Energy Supply by Fuel

A massive carbon Baseline & inertia

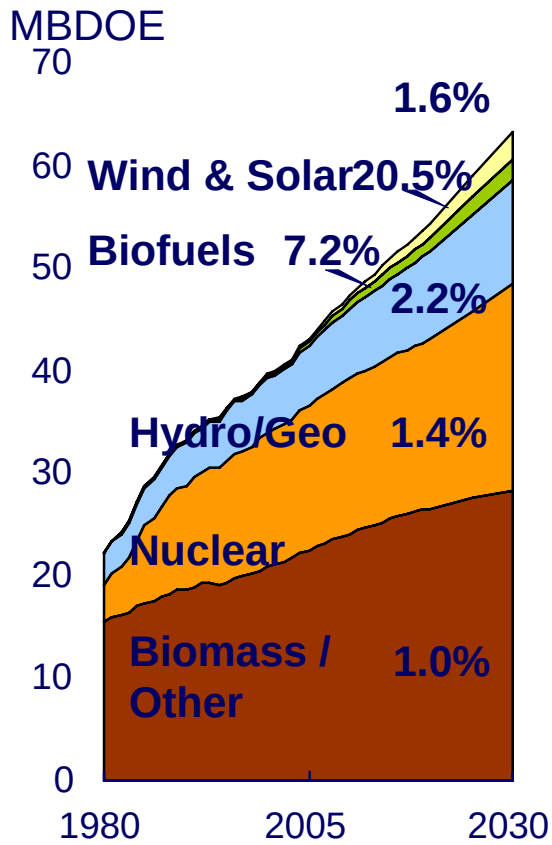
Sufficient opportunities exist

Fastest growth, smallest sectors

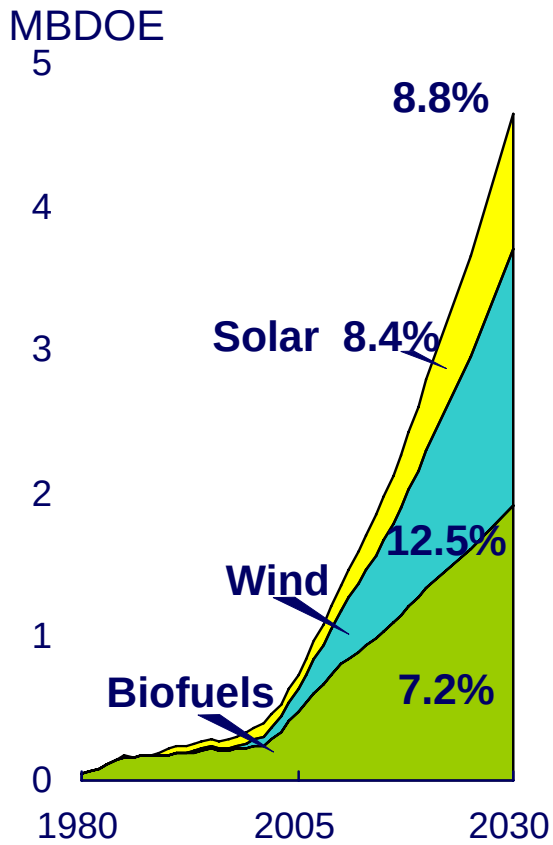
Fossil Energy



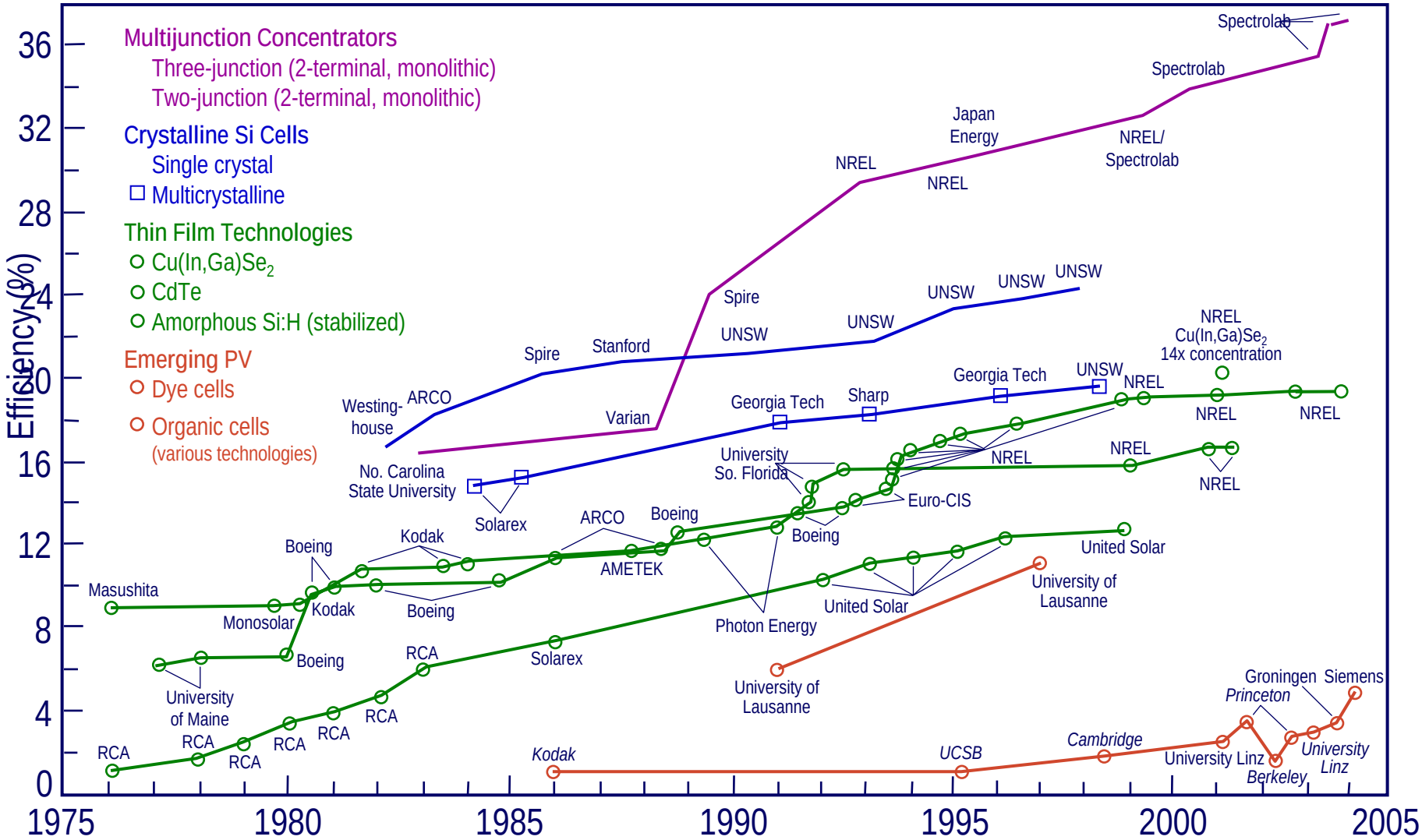
Other Energy



Wind, Solar & Biofuels



Best Research-Cell Efficiencies



Solar Energy for Many Applications

Moscone Center, SF: 675,000 W

Residential Solar: 1000 - 4000 Watts/home

CA Solar Initiative/Million Solar Roofs:

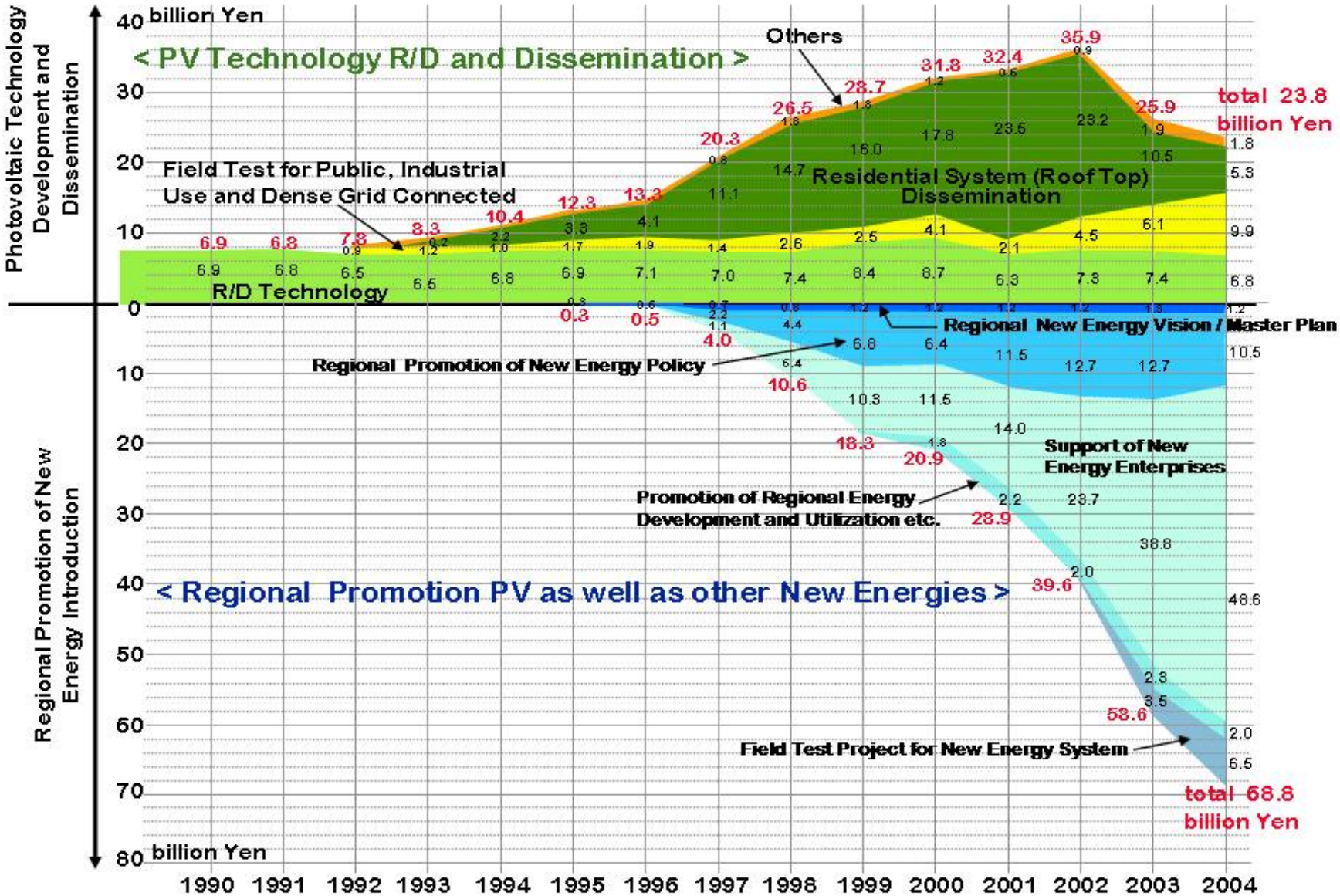
3,000 - 10,000 MW of solar to be built

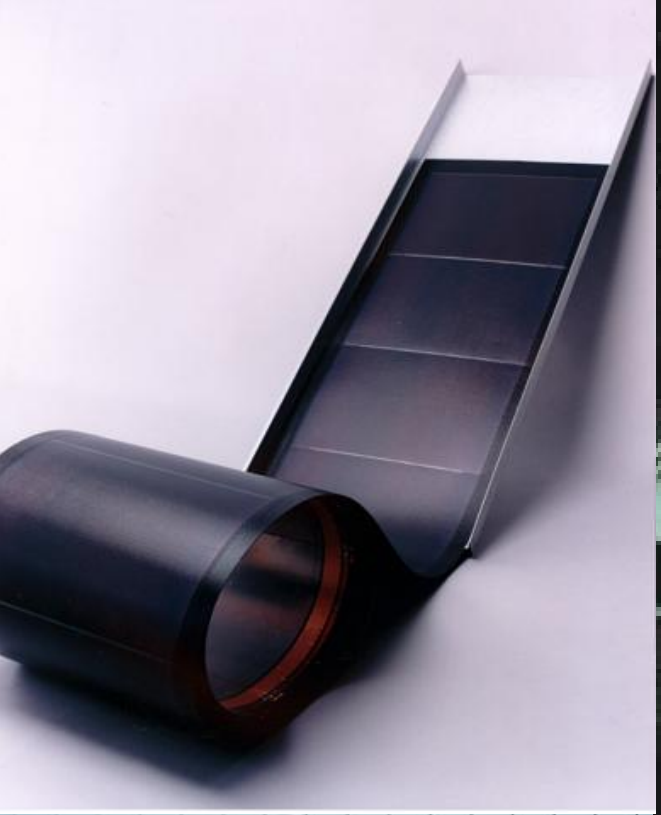
Kenyan PV market: Average system: 18W

Largest penetration rate of any nation

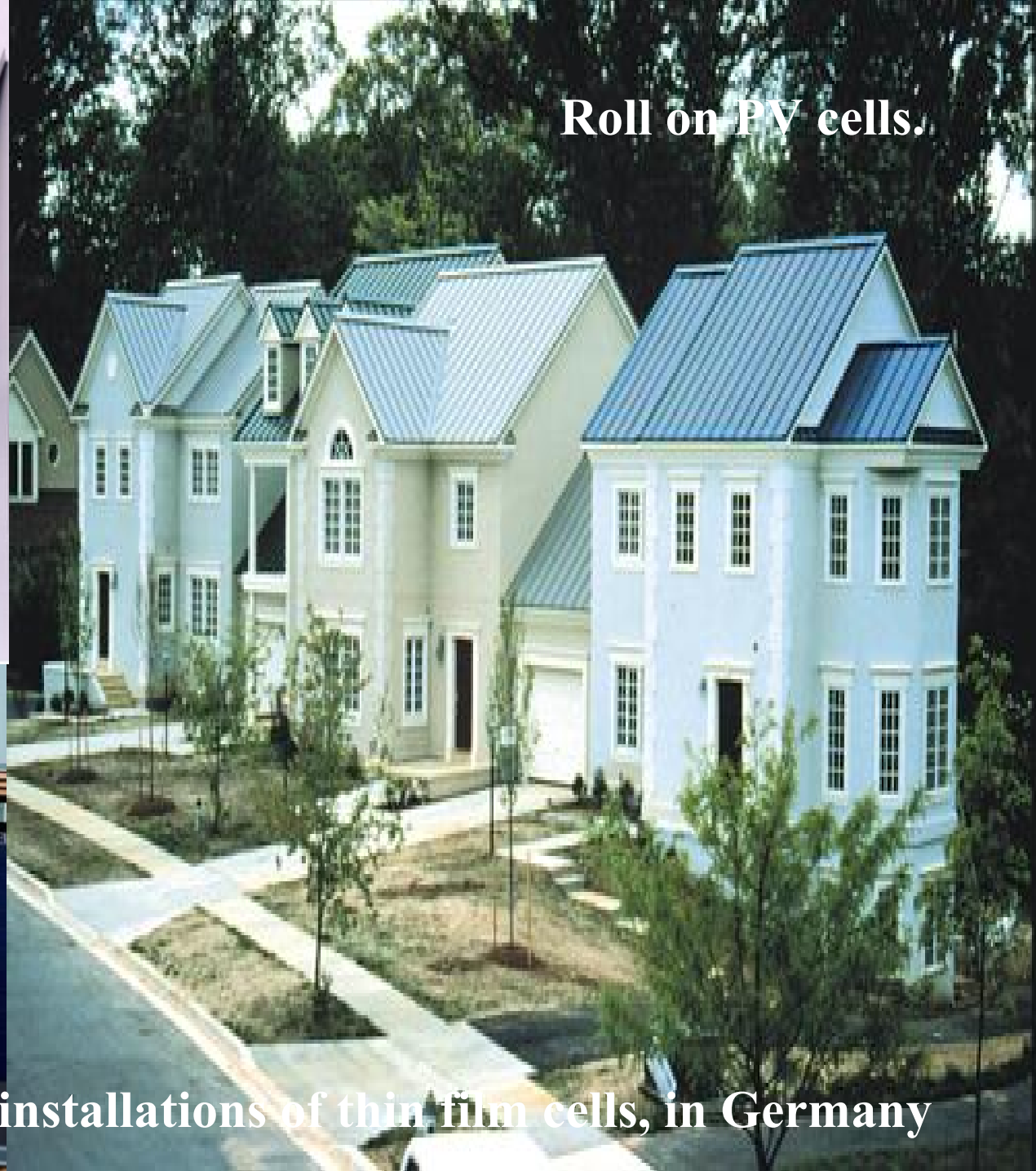
	California	Japan
2005 Annual PV Installations	50 MW	290 MW
Average Cost for Residential System	$8.8/Wac	$7.4/Wac
Average Cost Reduction from 99-04	5.2%/year	8.9%/year

Japanese “Sunshine” Program



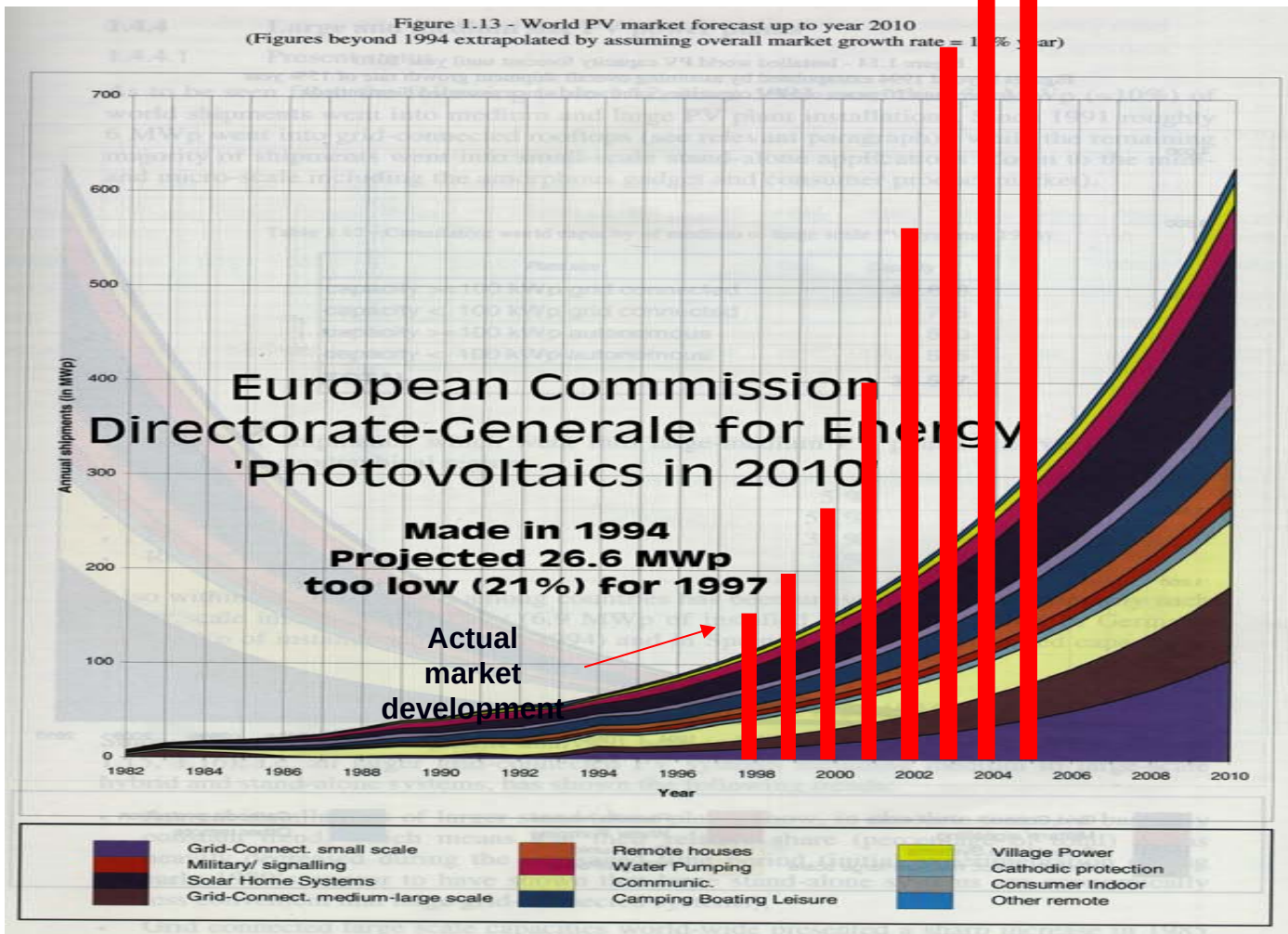


Solar photovoltaic installations of thin film cells, in Germany



Roll on PV cells.

Actual Growth vs. Historic Forecasts



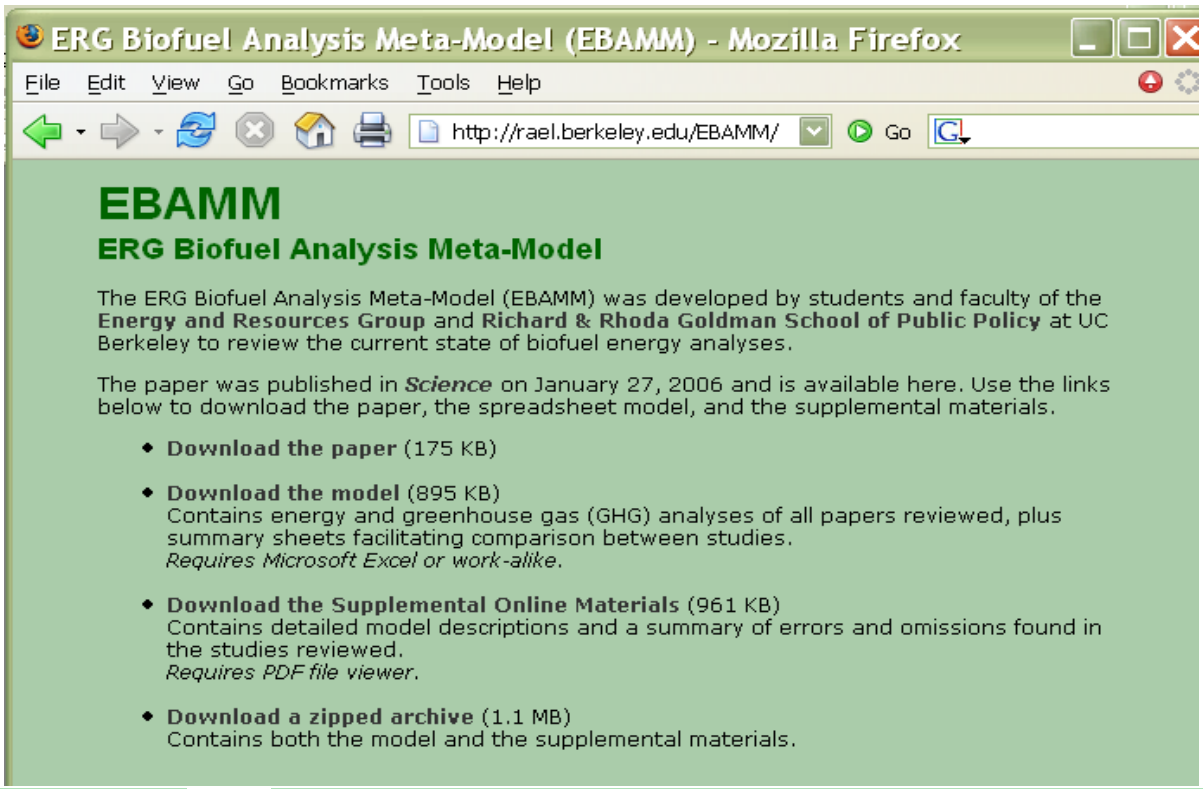
REPORTS

27 JANUARY 2006 VOL 311 SCIENCE www.sciencemag.org

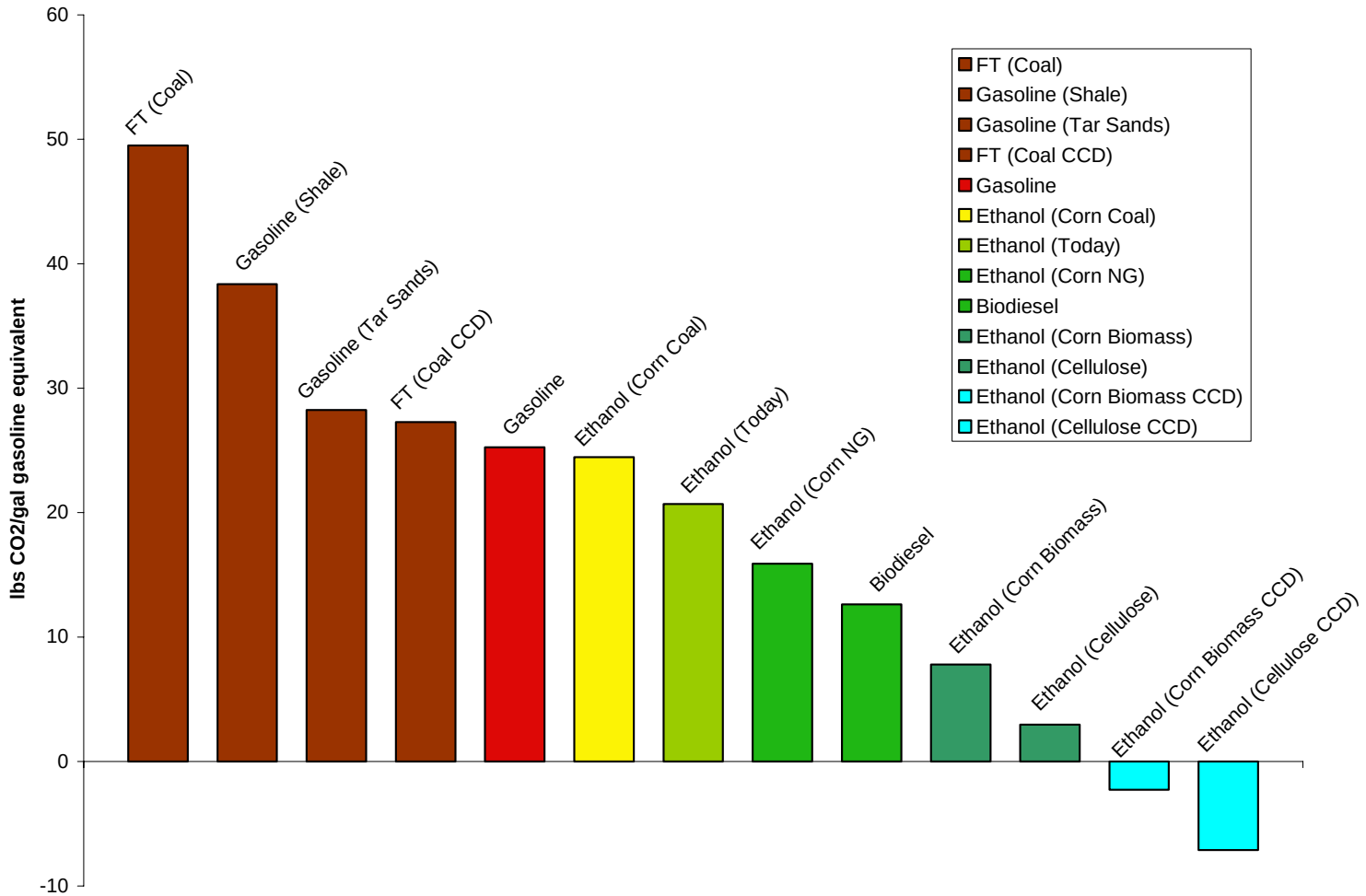
Ethanol Can Contribute to Energy and Environmental Goals

Alexander E. Farrell,[1*] Richard J. Plevin,[1] Brian T. Turner,[1,2] Andrew D. Jones,[1] Michael O'Hare,[2] Daniel M. Kammen[1,2,3]

Open access, online, biofuel calculator tools: http://rael.berkeley.edu/ebamm



An Alternative Fuel is Not Necessarily a Low-Carbon Fuel, but it can be



Low Carbon Fuel developments worldwide

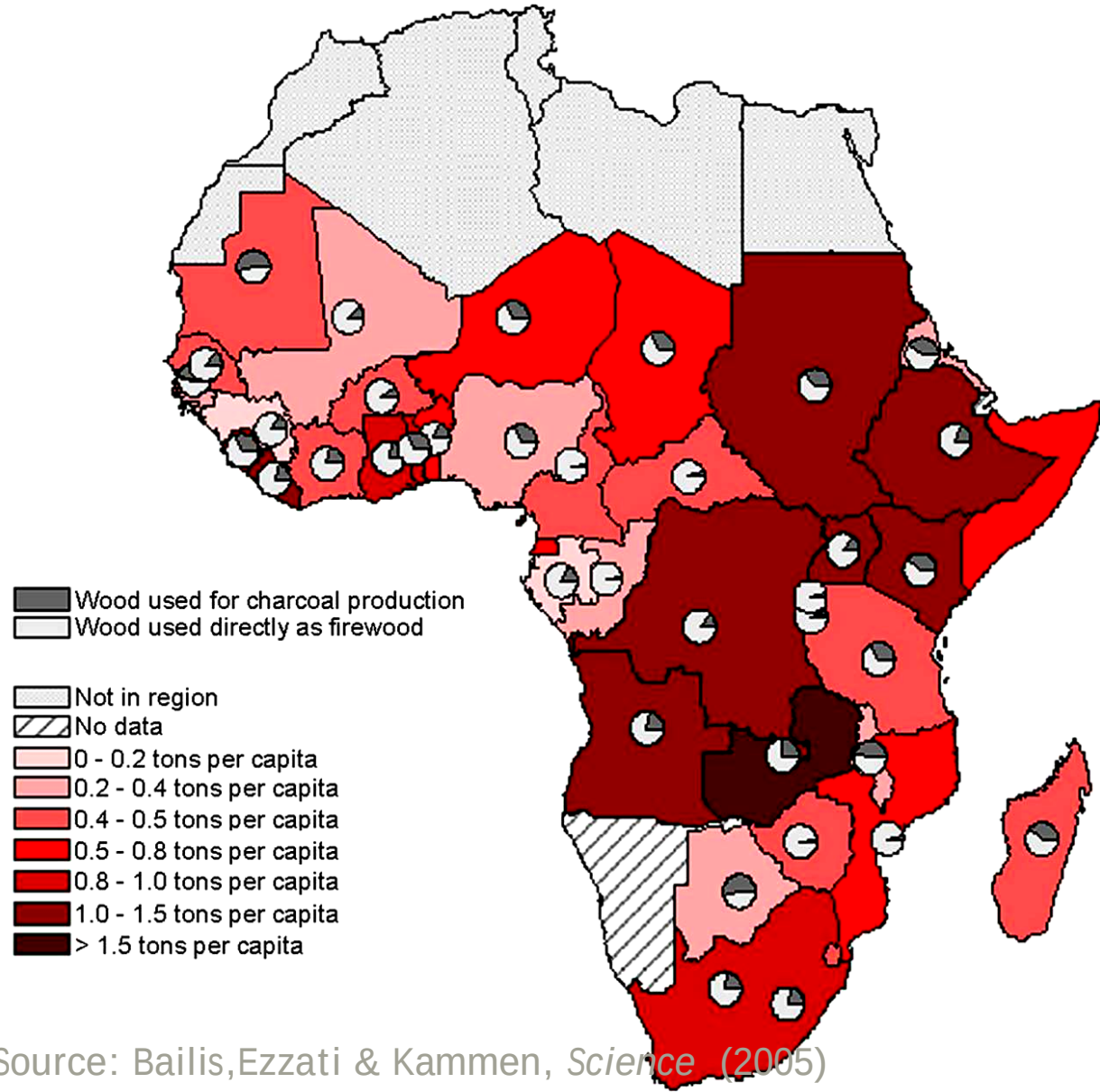
- **Renewable Fuel Standard (RFS)**
  - United States: double biofuel use by 2012 to ~6% of gasoline.
  - UK Renewable Transportation Fuel Obligation (RTFO): 5% by 2010
- **Low Carbon Fuel Standard (LCFS)**
  - California: regulations to be in effect 2010
  - Federal bills: Boxer, Feinstein, Obama, Inslee, etc.
  - European Union: monitoring in 2009, reductions start in 2011
  - United Kingdom: RTFO requires GHG monitoring, pilot in 2007
  - Others: BC, WA, OR, AZ, NM, MN, EU ...
- **Current and forthcoming analysis**
  - *Draft Carbon Reporting Methodology under the RTFO.* E4Tech. Dec06
  - *Sustainability Reporting within the RTFO.* ECOFYS. Feb07
  - *Creating Markets for Green Biofuels*. UC Berkeley study. April07
  - *AB1007 Well-to-Wheels Analysis.* CEC/CARB study. May07
  - *Low Carbon Fuel Standard for California*. UC Berkeley/Davis. May07

Sub-Saharan Africa's wood-energy consumption is the highest in the world

Primary production of biomass energy in 2000 (10^{18} Joules)

Sub Saharan Africa	10.2
China	8.9
India	8.4
Latin America	3.2

Source: IEA, 2003

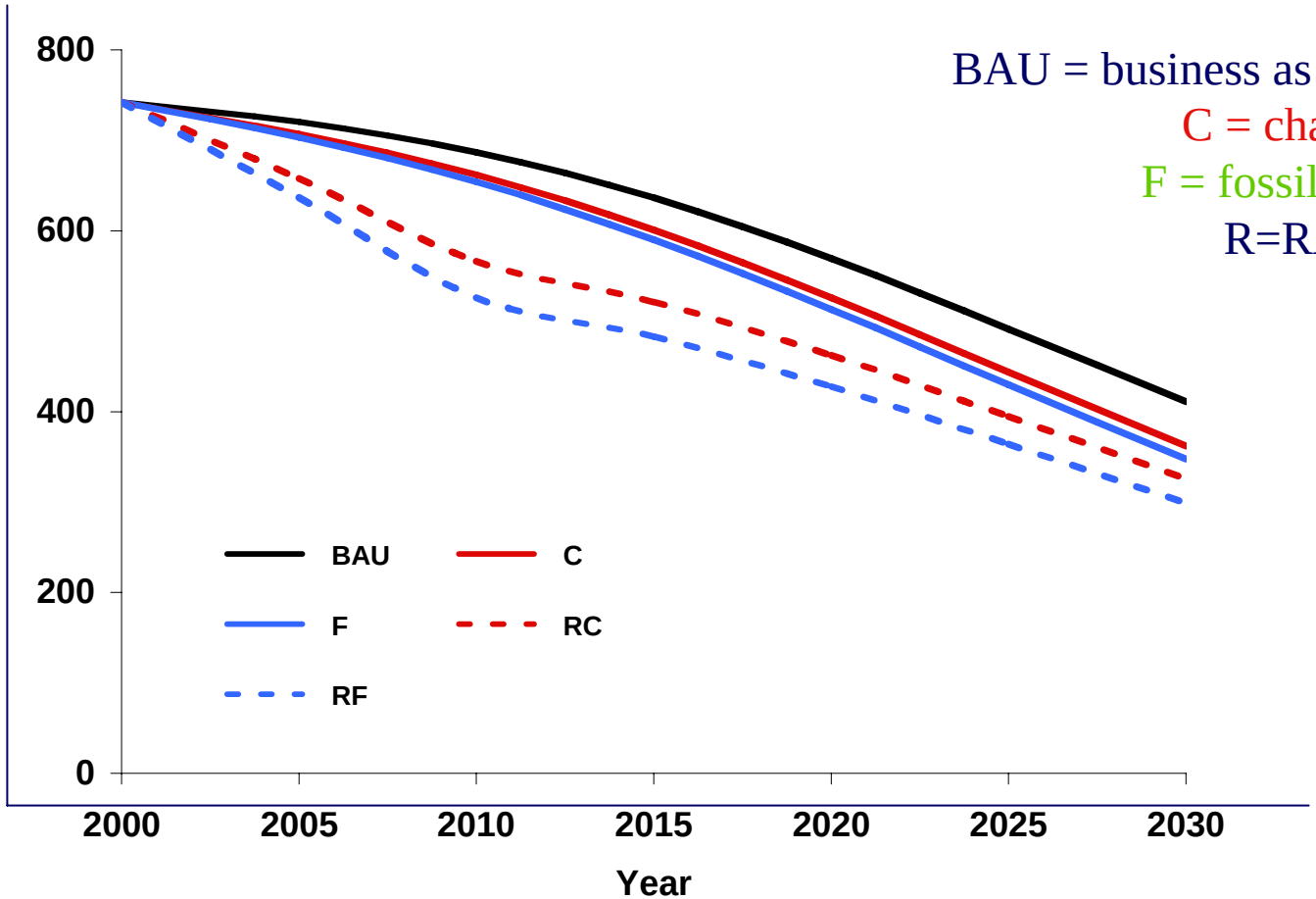


Source: Bailis,Ezzati & Kammen, *Science* (2005)

Charcoal is *not* just an African issue

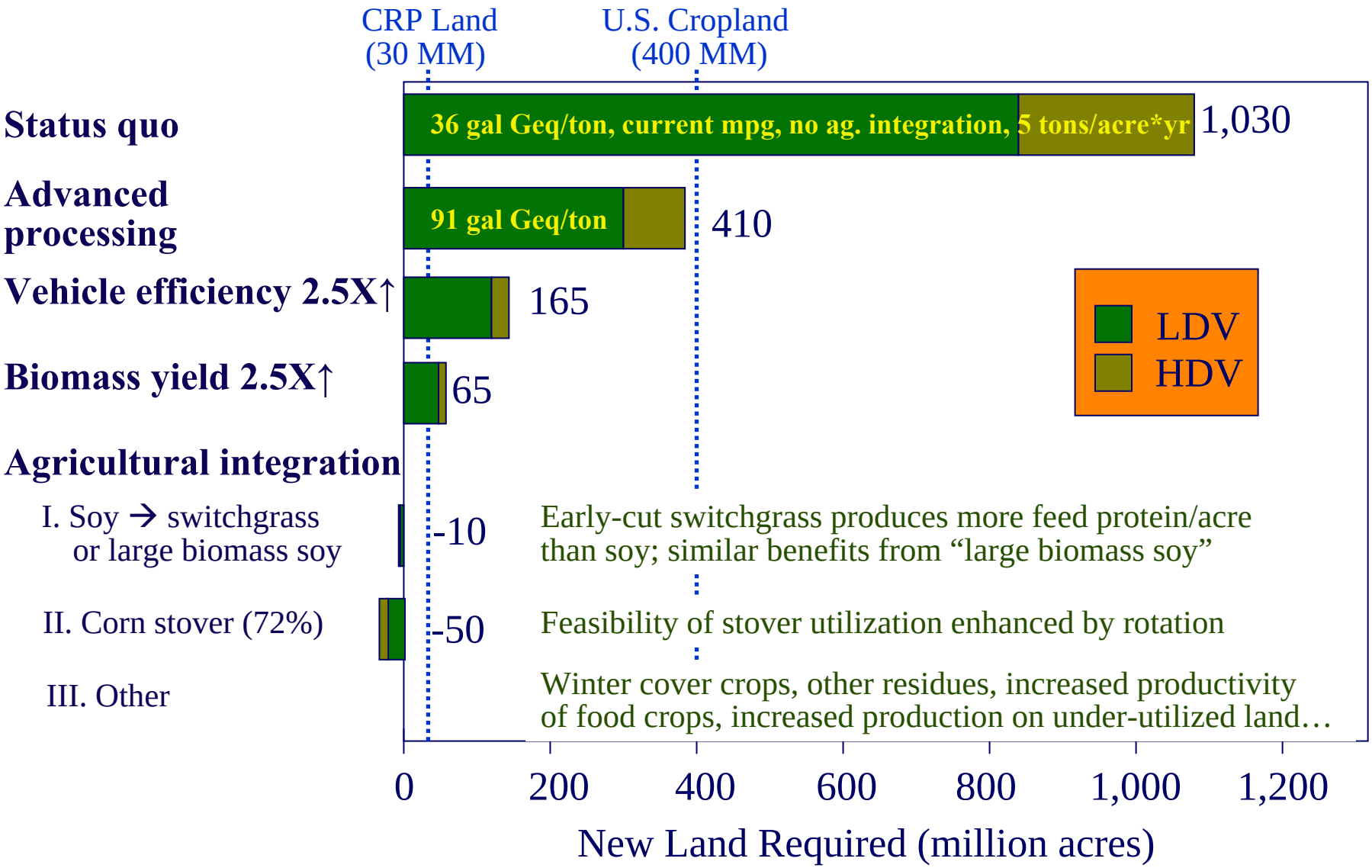
Expected Annual Deaths: Leading Causes for African Child and Women

Millions of avoidable deaths; biofuels can be comparable to fossil fuels



Bailis, Ezzati & Kammen *(2005) Science*

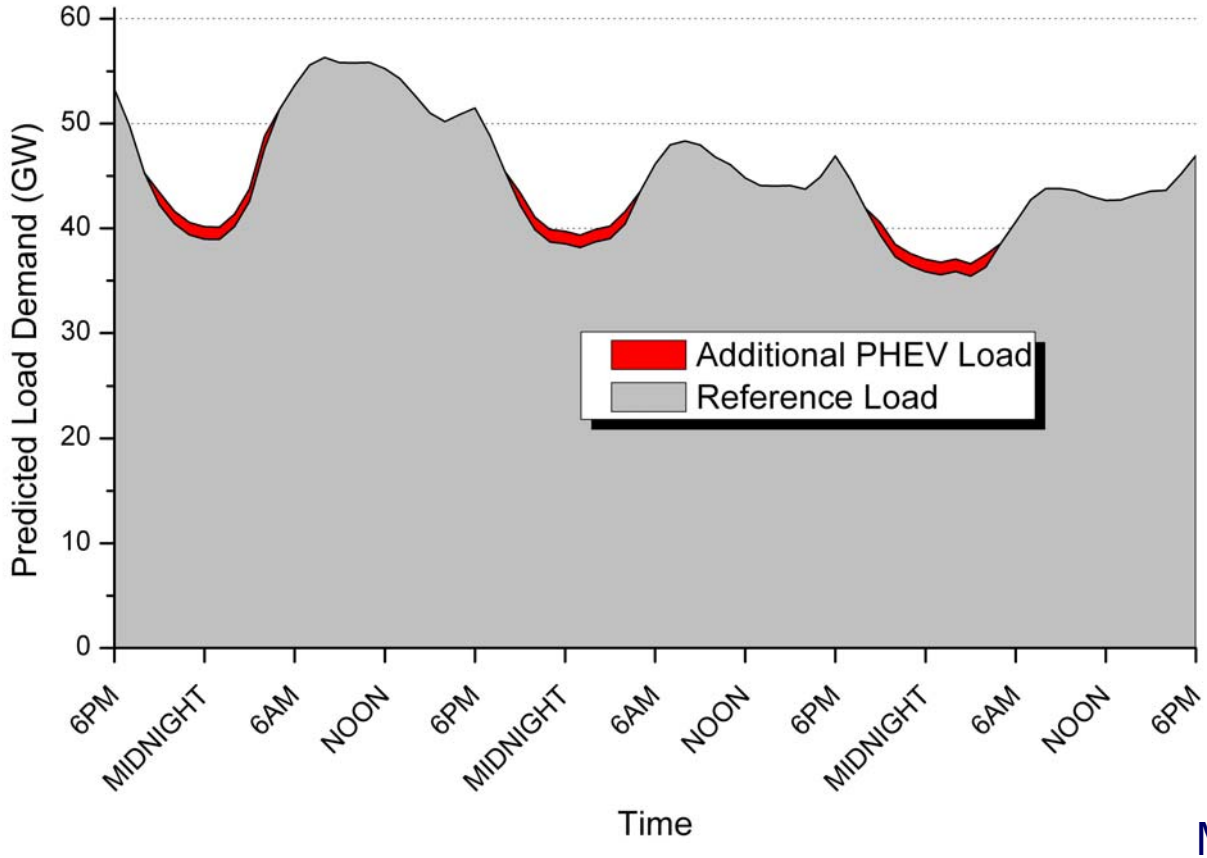
Land Required to Satisfy Current U.S. Mobility Demand



U.S. mobility demand, the largest per capita in the world, could be met from land now used for agriculture while maintaining food production (L. Lynd)

Plug In Partners / e.g. CalCars.org

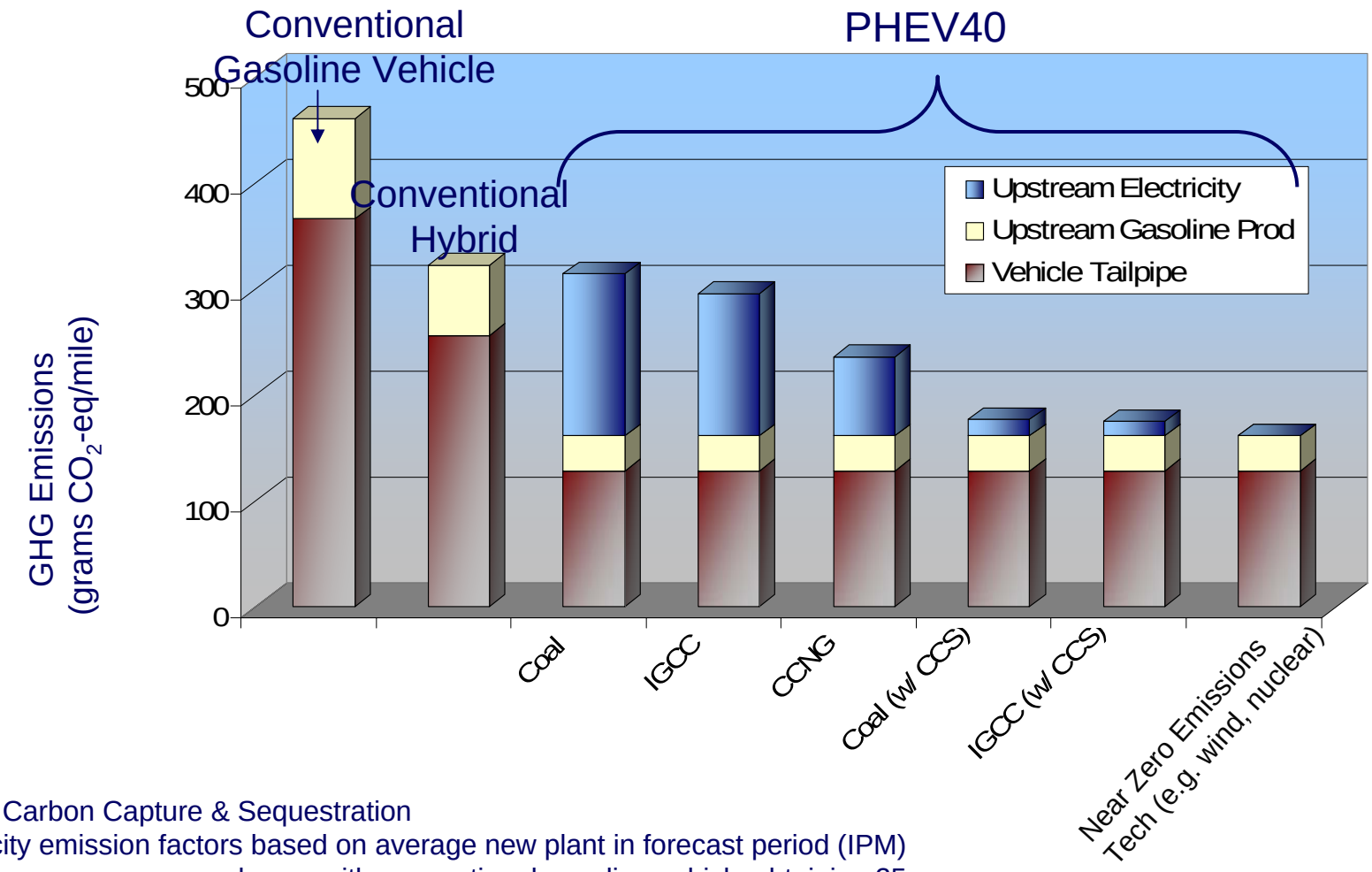
PHEV Off-Peak Electricity Demand



Model: IPM

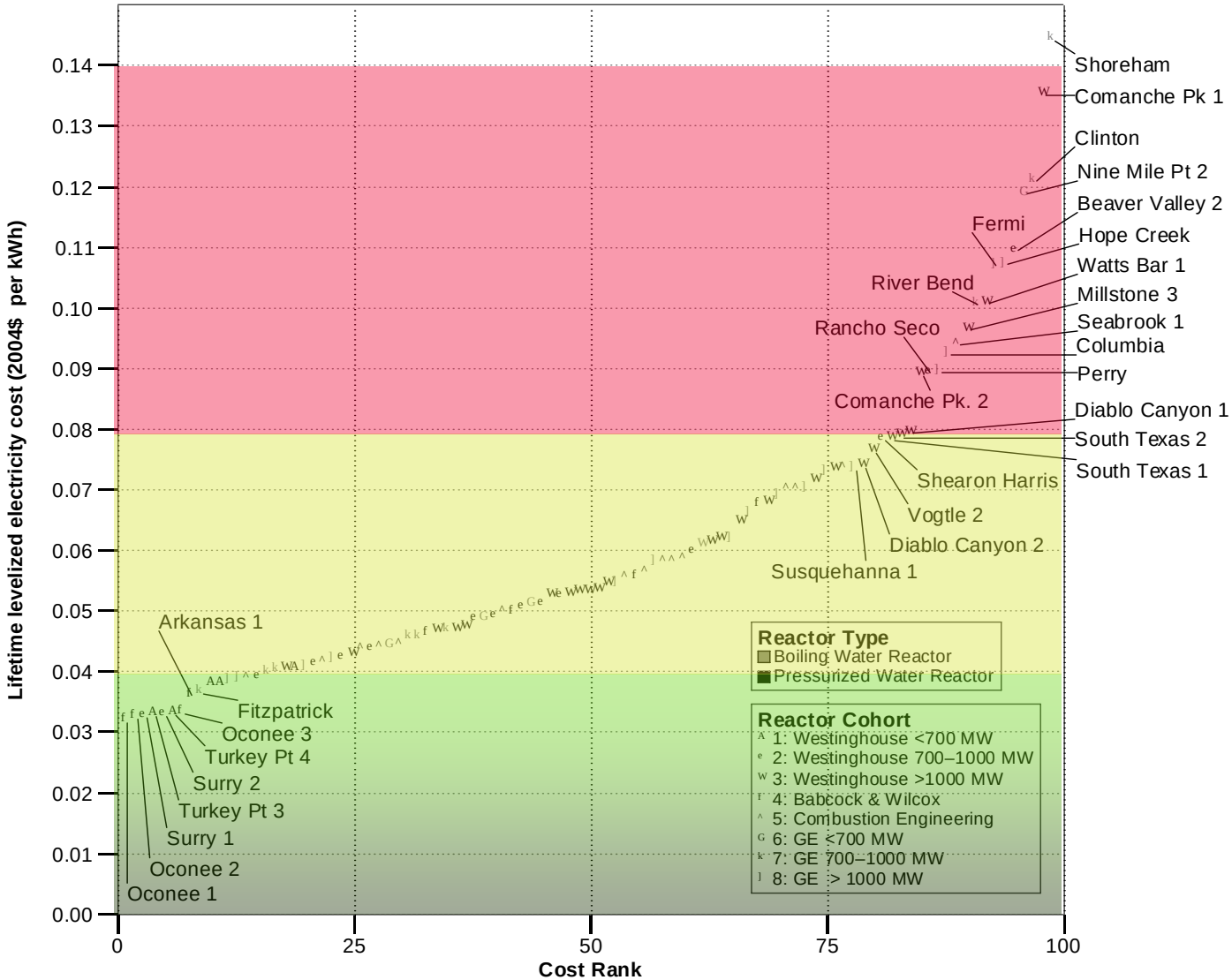
- Additional load from PHEVs is small
- PHEVs could be charged mostly via base-load filling during evenings and nights, when electricity costs are low

Choice of Electricity Generation - PHEV GHG Emissions



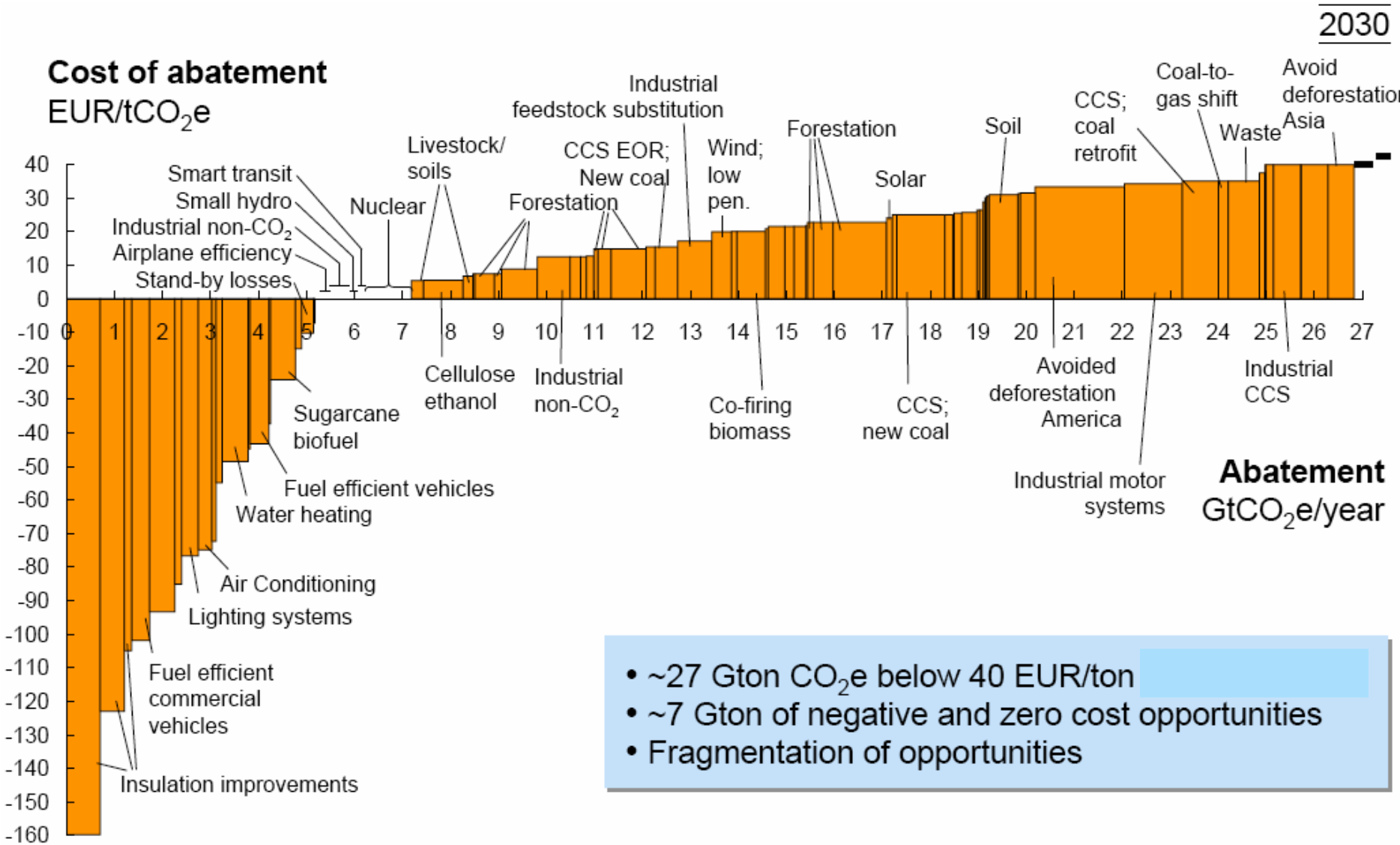
CCS = Carbon Capture & Sequestration
Electricity emission factors based on average new plant in forecast period (IPM)
Mid-size passenger cars shown, with conventional gasoline vehicle obtaining 25 mpg

The Cost of Nuclear Power from the U. S. Civilian Reactor Fleet



Hultman, Koomey & Kammen (2007) *ES&T*

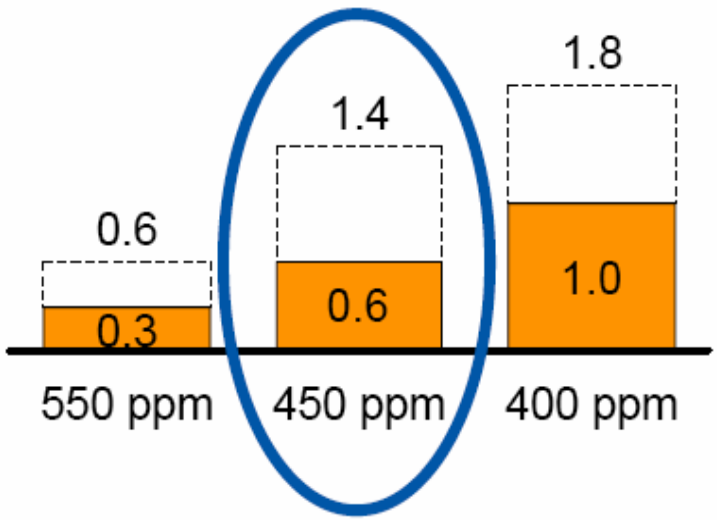
Global CO_2 Abatement Opportunities



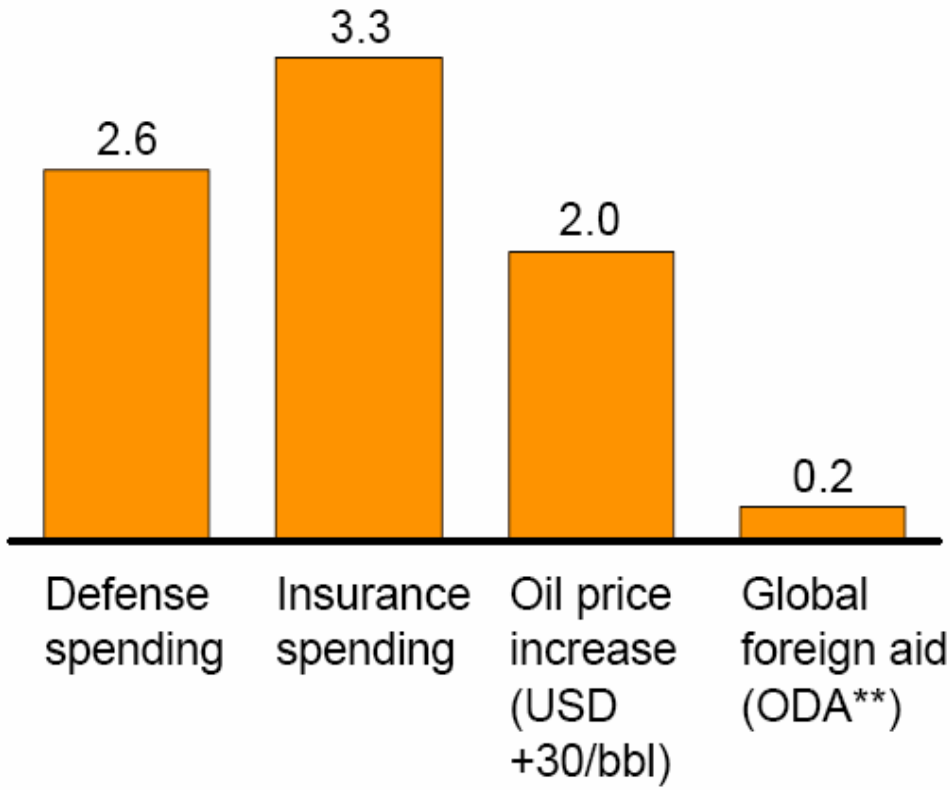
- ~27 Gton CO_2e below 40 EUR/ton
- ~7 Gton of negative and zero cost opportunities
- Fragmentation of opportunities

Comparing Cost Estimates

Estimates of total abatement cost for the global society*
% of global GDP 2030

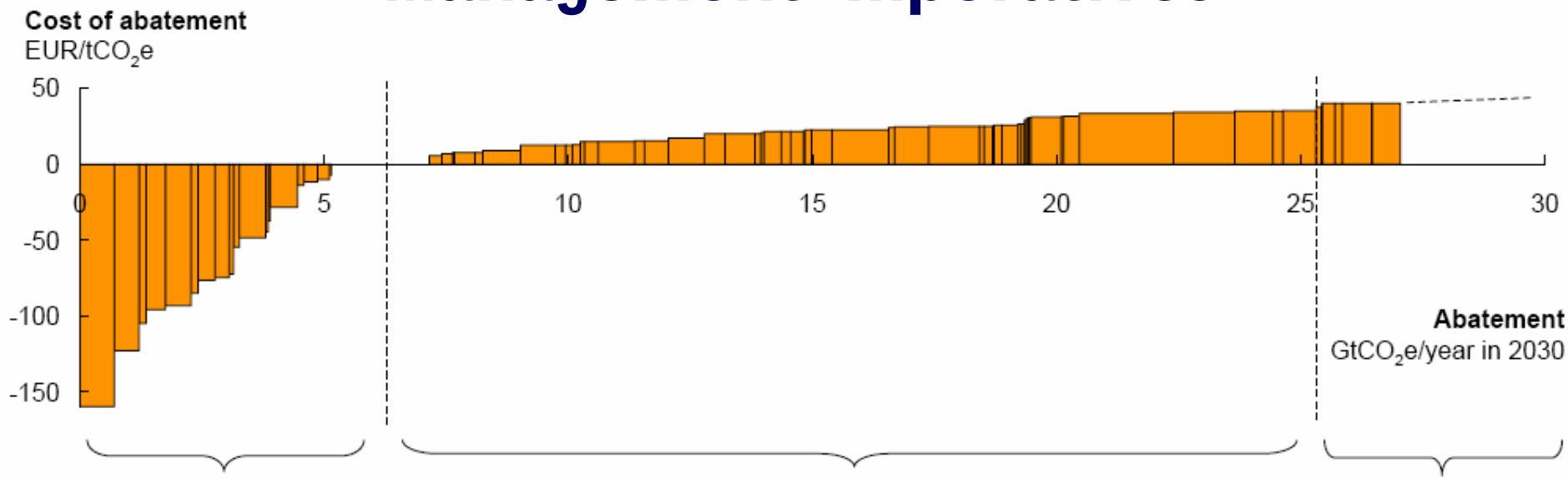


Comparables
% of global GDP 2005



* Lower boundary: Opportunities addressed in order of increasing cost and negative costs are set to zero; upper boundary: Average cost EUR 40/ton

Technology Options and Costs to Management Imperatives



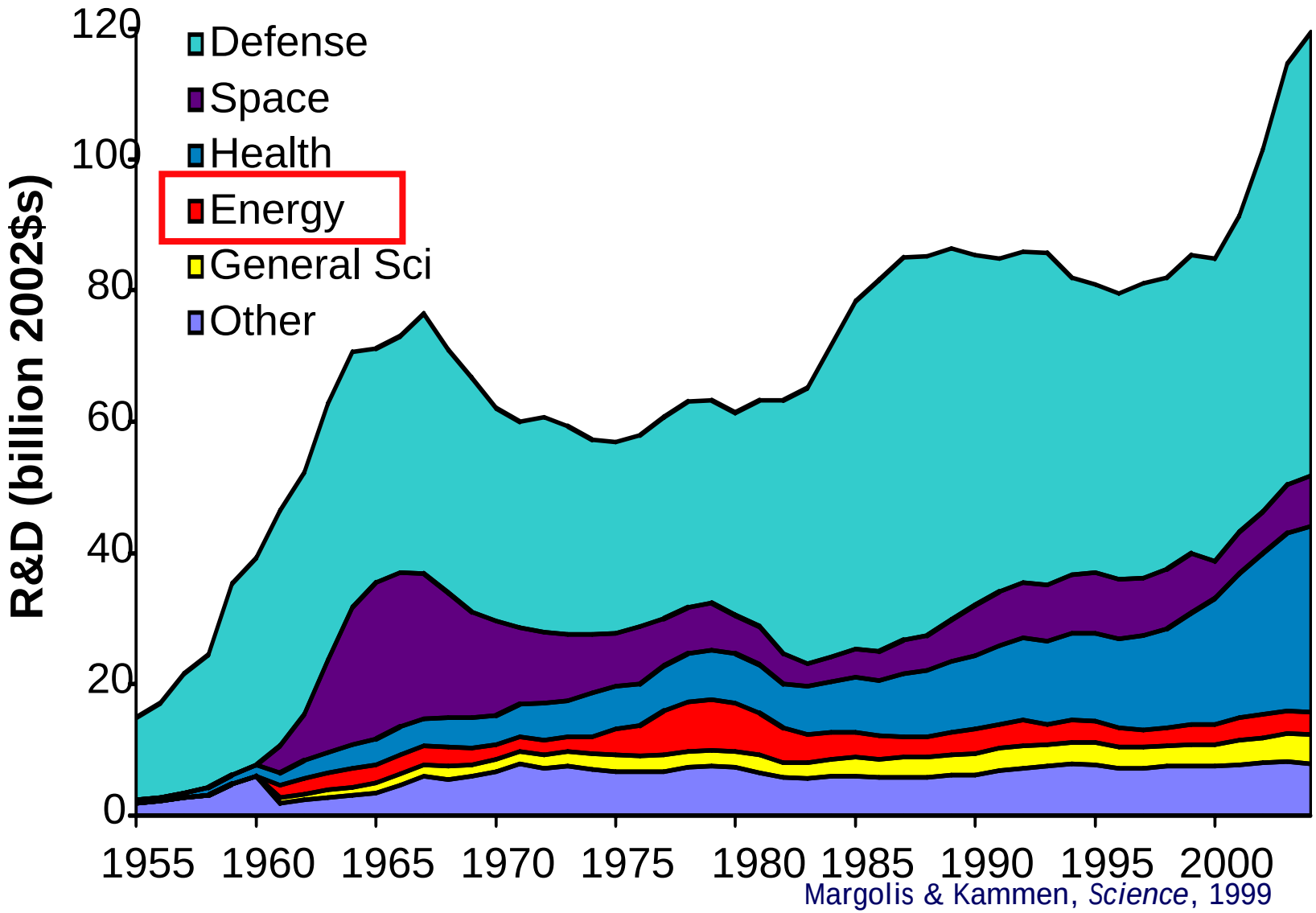
A **Policies/ standards for buildings and transportation, or a certificate system**

B **Long-term stable international system for power and industry**

D **International system for agriculture and deforestation**, linked to the overall developing world agenda

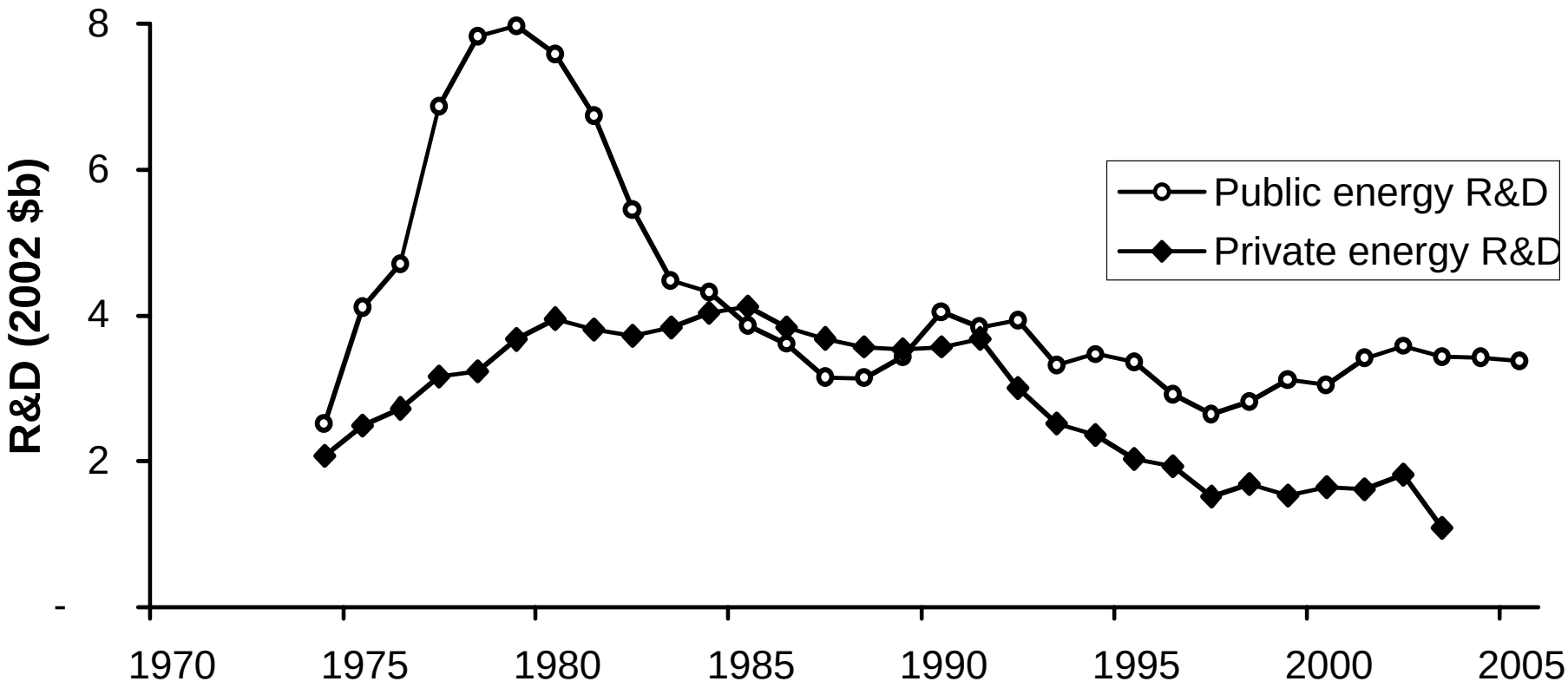
C **Mechanism to drive selected key technologies down the learning curve**

Federal R&D Investments, 1955 - 2004



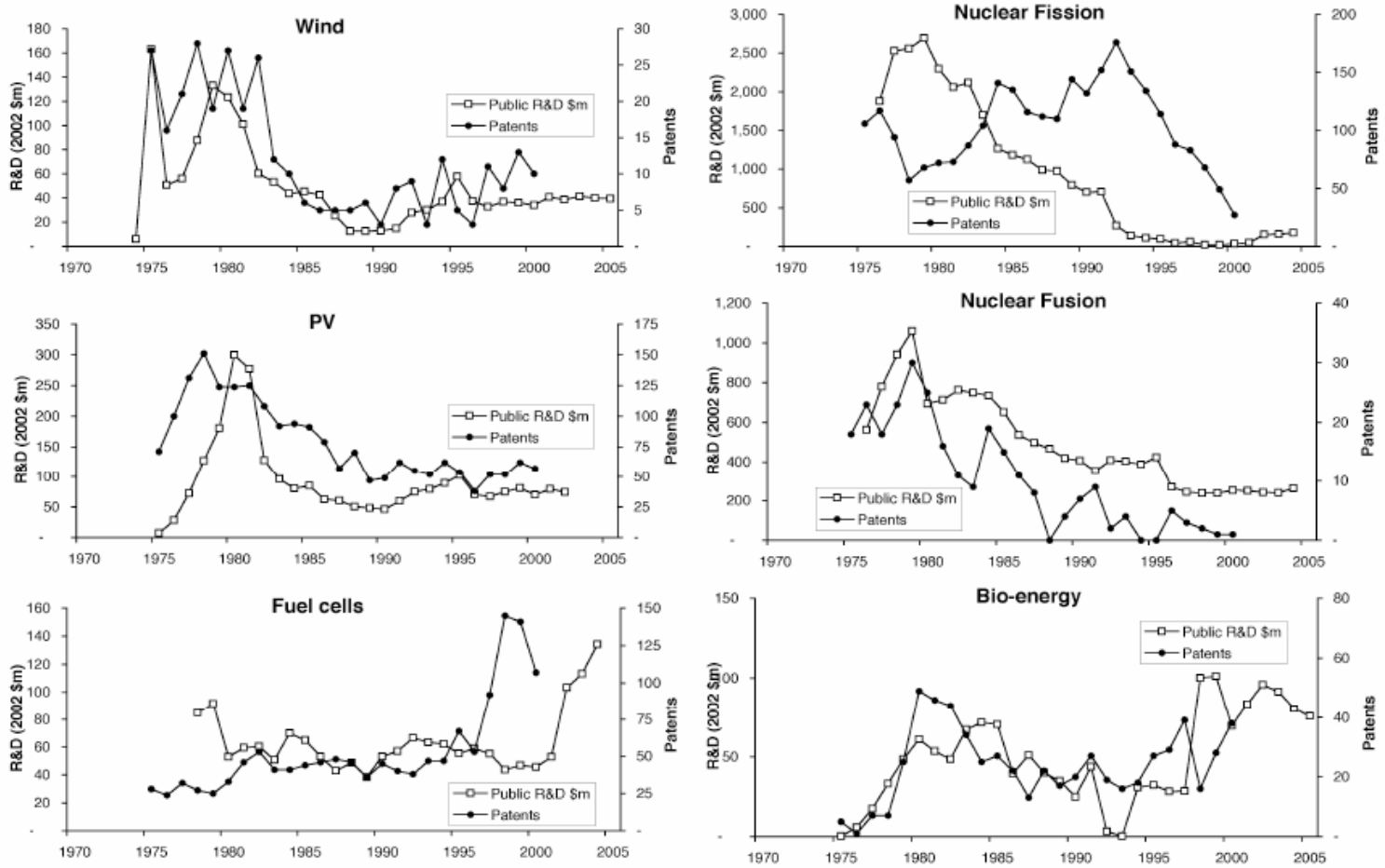
Margolis & Kammen, *Science*, 1999

If you think US public sector energy R&D funding is doing poorly …



Kammen and Nemet (2005)
"Reversing the incredible shrinking energy R&D budget," *Issues in Science & Technology,* **Fall**, 84 – 88.

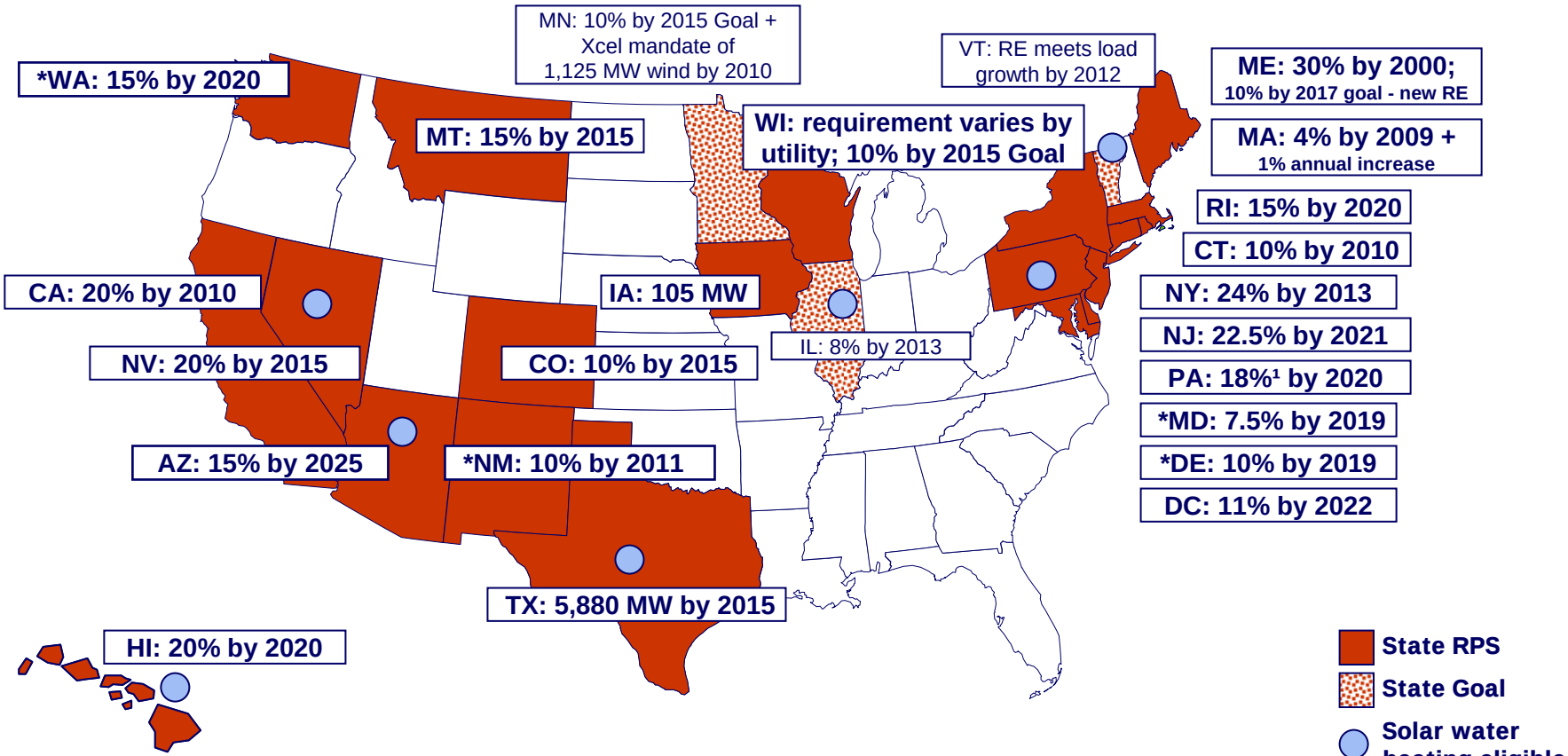
Patents and R&D Funding Correlated



Kammen and Nemet (2005)
"Reversing the incredible shrinking energy R&D budget," *Issues in Science & Technology,* **Fall**, 84 – 88.
And Nemet, dissertation, 2007

Renewable Energy Portfolio Standards

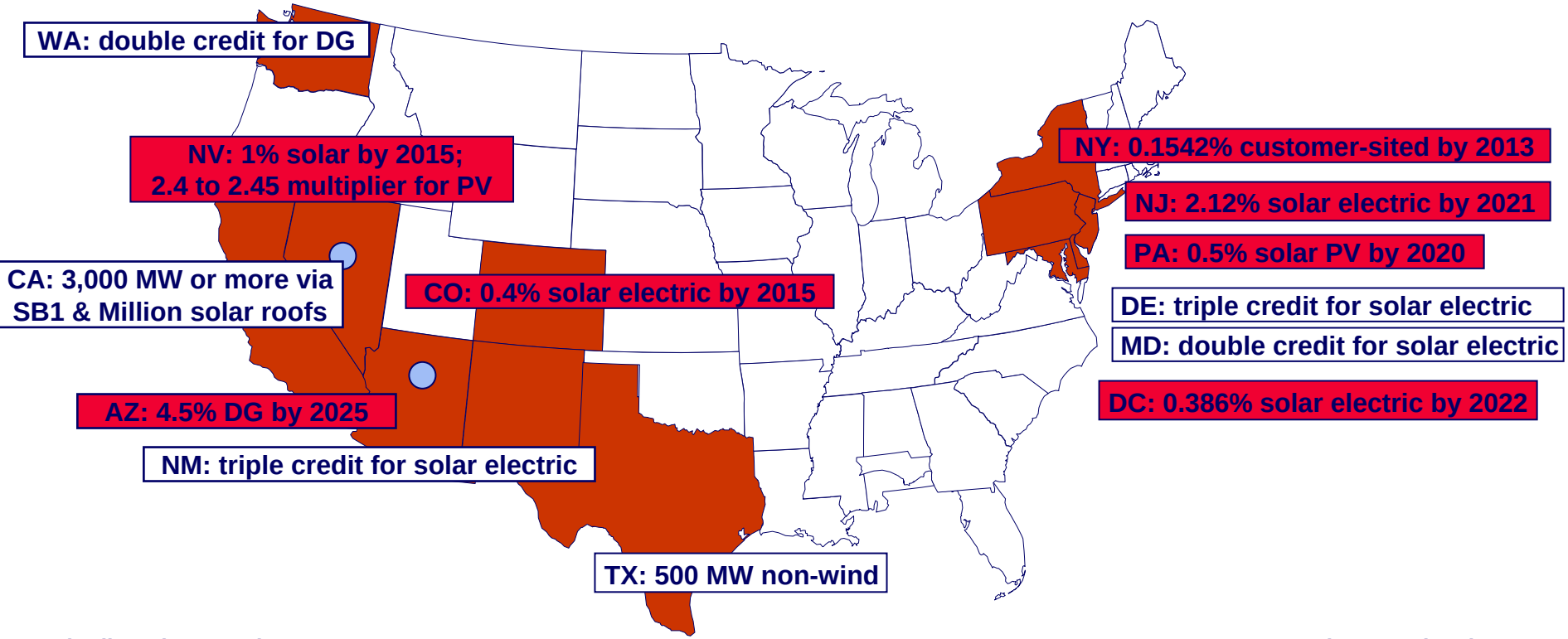
23 states + DC, and counting



*** Increased credit for solar or other customer-sited renewables**

PA: 8% Tier I (renewables)

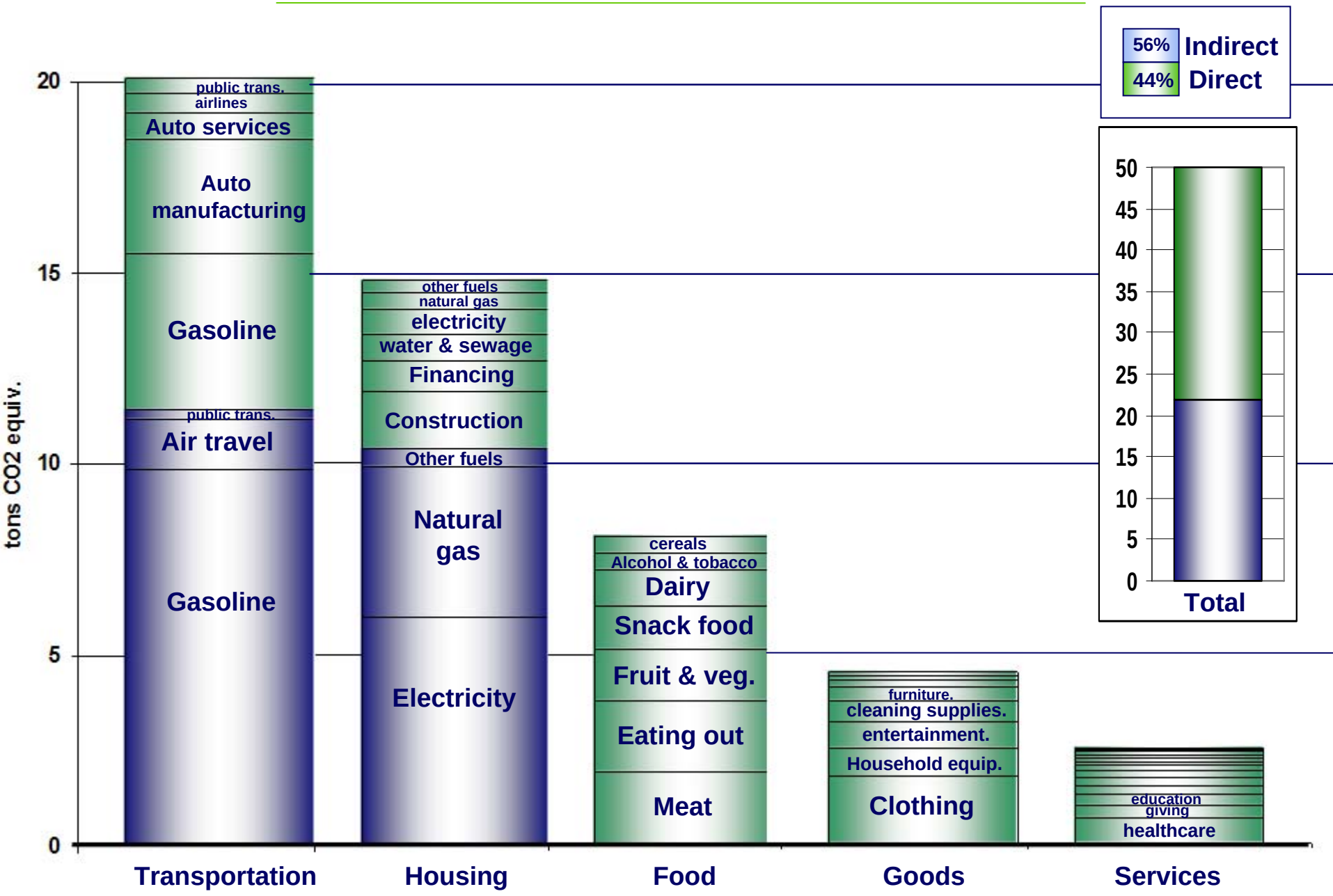
Solar & Distributed Generation Provisions in RPS Policies



DG: Distributed Generation

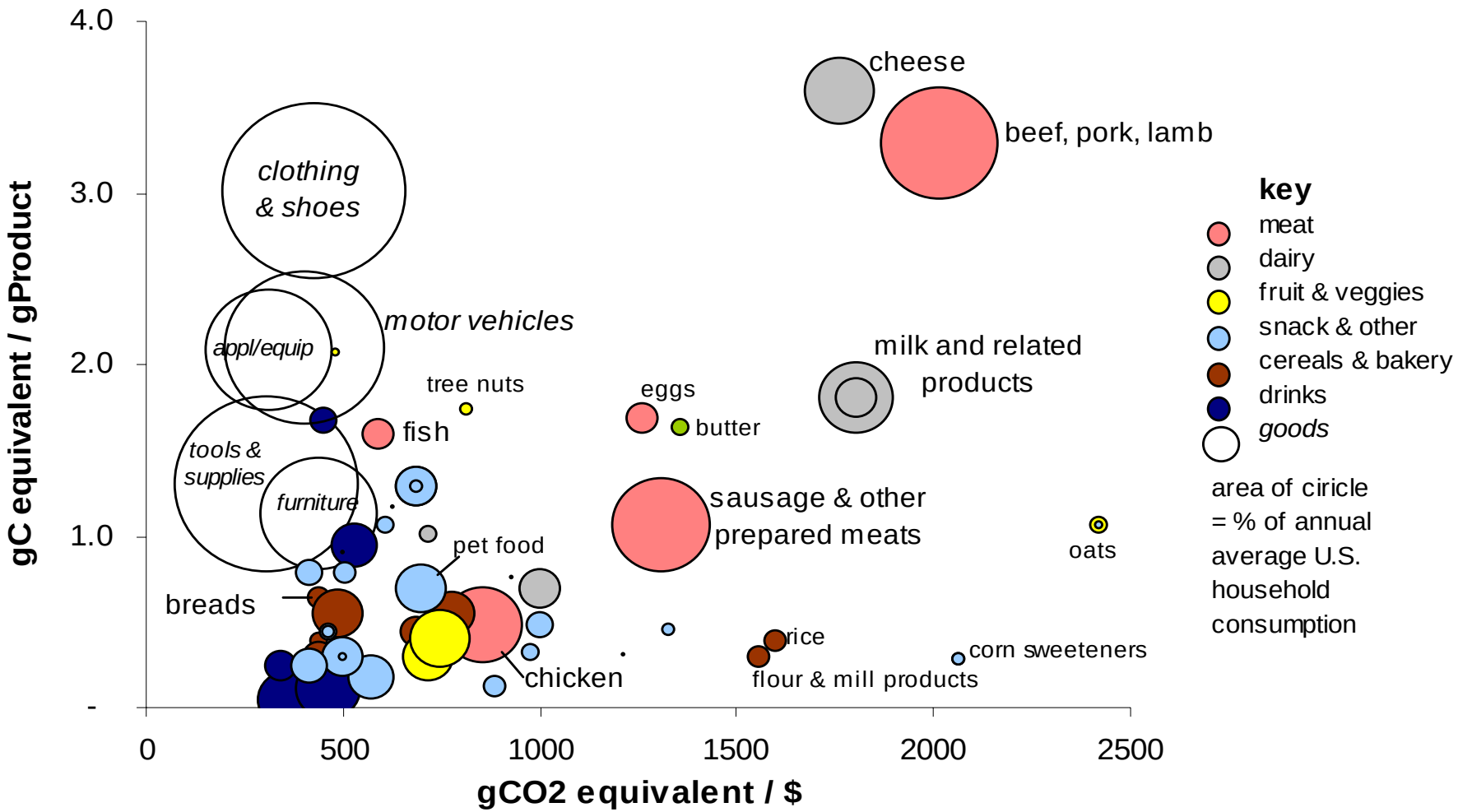
Solar water heating counts towards solar set-aside

Summary of GHG Emissions for Typical U.S. Household (LEAPS Results) 50 Metric tons of CO_2 equivalent gases



Greenhouse Gas Emissions: Lifecycles & Lifestyle Sources

(Jones, Horvath & Kammen, in press)




Solar roofing & off-site wind purchases
All materials from reclaimed former building

The Path Ahead

- Clean energy sources today are evolving rapidly, but are a small component of our overall energy system
- Rapid growth of the clean energy sector will require a coordinated commitment to *technology push* and *demand pull*
  - Aggressive R&D will need to be coupled with strong support for clean energy market expansion
  - Business and consumer involvement is vital
- One California per year, at minimum, is needed, and we must be successful in making AB32/Ex. Order S-3-05 work
- Pricing carbon/greenhouse gas emissions is vital to moving from sector support strategies to long-term sustainability policies

Illness Reduction Observed in Kenya
(ARI = acute respiratory infection)